MĀRIS KĻAVIŅŠ,
AZAMAT AZIZOV,
JĀNIS ZAĻOKSNIS

ENVIRONMENT, POLLUTION, DEVELOPMENT: THE CASE OF UZBEKISTAN

Rīga, 2014

Māris Kļaviņš, Azamat Azizov, Jānis Zaļoksnis. ***Environment, pollution, development: the case of Uzbekistan.*** Riga, UL Press, 2014

The book is prepared with the support of Project «Master Program in Environmental Science and Sustainable Development with Focus on Water Management for Uzbekistan Higher Education – UZWATER» and with the support of University of Latvia.

Translation by **Andra Damberga**

Figures prepared by **Laura Kļaviņa**

Layout by **Ieva Tiltiņa**

Cover photo: **Māris Kļaviņš**

ISBN 978-9984-45-888-5

CONTENTS

1. INTRODUCTION 7

2. UZBEKISTAN: A COUNTRY WITH HISTORY, PRESENT AND FUTURE 9
   2.1. Geographic situation and climate 9
   2.2. Natural resources of Uzbekistan 11
   2.3. Biological resources 16
   2.4. Natural ecosystems 18

3. WATER RESOURCES OF UZBEKISTAN 21
   3.1. Hydrological cycle 21
   3.2. Water resources of Uzbekistan 26
   3.3. River Amu Darya 30
   3.4. River Syr Darya 34
   3.5. The Aral Sea 36

4. HUMANS AND THE ENVIRONMENT 43
   4.1. Systems of the Earth: the lithosphere, hydrosphere, atmosphere and biosphere . 43
      4.1.1. Environmental science – a science of environmental systems 43
      4.1.2. Atmosphere, hydrosphere and lithosphere 45
      4.1.3. Biosphere 49
   4.2. Cycling of elements and energy on the earth 58
      4.2.1. Energy flow and the Earth's climate 60
      4.2.2. Carbon cycle 65
      4.2.3. Nitrogen biogeochemical cycle 68
      4.2.4. Phosphorus biogeochemical cycle 72

5. GLOBAL ENVIRONMENTAL PROBLEMS 75
   5.1. Environmental pollution and environment quality degradation 75
   5.2. Global environmental pollution problems 77
      5.2.1. Earth's ozone layer and the consequences of its depletion 77
      5.2.2. Global warming 81
   5.3. Regional environmental pollution effects 87
      5.3.1. Sulphur compounds 87
      5.3.2. Nitrogen compounds 89
      5.3.3. Dust and aerosols 91
   5.4. Indoor air pollutants 93

6. ACTION OF TOXIC SUBSTANCES IN THE ENVIRONMENT –
   BASIC CONCEPTS OF ECOTOXICOLOGY 97
   6.1. Concept of ecotoxicology 97
   6.2. Effects of toxic substances on living organisms 98
   6.2. Toxicity assesment of substances 104

6.3. Effects of pollutants and physical factors on humans and ecosystems 107
6.3.1. Types of toxic effects 107
6.3.2. Effects of environmental pollutants and factors on human beings 108
6.3.3. Effects of environmental pollutants on the endocrine system 109
6.3.4. Genotoxic effects of environmental pollutants and factors 112
6.3.5. Carcinogenic effects of environmental pollutants and factors 113
6.3.6. Teratogenic substances 115

7. AIR POLLUTION 119
7.1. Sulfur compounds in the atmosphere 126
7.2. Nitrogen compounds in the atmosphere 132
7.3. Carbon compounds in the atmosphere 136
7.4. Dust and aerosols in the atmosphere 137
7.5. Halogenated organic compounds in the atmosphere 144
7.6. Urban air pollution problems 147
7.7. Acid precipitations 150
7.8. Indoor air pollutants 154

8. WATER POLLUTION 159
8.1. Water resources and their use 162
8.2. Natural water composition and conditions of formation 165
8.3. Most significant water pollution problems 168

9. POLLUTION OF SOIL 187
9.1. Contamination of soil with organic substances 190
9.2. Contamination of soils with inorganic substances 196
9.3. Soil desertification and salinization 200

10. INTERNATIONAL COOPERATION IN ENVIRONMENTAL PROTECTION AND SUSTAINABLE DEVELOPMENT 203
10.1. Mutual cooperation and development 203
10.2. International environmental issues 204
10.3. Institutions involved in international environmental protection 209
10.3.1. International environmental organisations 211
10.3.2. Environmental activist groups 213
10.3.3. International corporations 214
10.4. Role of science and scientists in identification and tackling of environmental problems 216
10.5. Development of international cooperation 218
10.5.1. First phase: sea resources 219
10.5.2. Second phase: activities of the environmental protection movement and the united nations 221
10.5.3. Third phase: from Stockholm (1972) to Rio de Janeiro (1992) 223
10.5.4. Fourth phase: the period of integration 225
10.6. Recent tendencies in international cooperation on environmental protection and sustainable development 228

11. ENVIRONMENTAL MANAGEMENT: LEGISLATION, POLICIES, INSTITUTIONS 233
11.1. Legislation of environmental protection 233
11.1.1. Law as an environmental protection instrument 234
11.1.2. Law and environmental science 237
11.1.3. Law and environmental ethics 237
11.2. Legal principles of environmental protection 238
11.3. Process of enforcement of environmental legislation 242
11.3.1. Approaches to elaboration of legal documents 242
11.3.2. Environmental legislation instruments 244
11.3.3. Dialogue with society and the role of society in environmental protection 245
11.4. Environmental policy 247
11.5. Environmental management system – from vision to implementation 250
11.5.1. Discussion and approval of the environmental policy vision 251
11.5.2. Determination of environmental problems and their causes 252
11.5.3. Setting environmental policy objectives 256
11.5.4. Types of action to accomplish environmental policy objectives 258
11.5.5. Development of the programmes to accomplish environmental policy objectives 259
11.5.6. Implementation and control of the environmental action programme or plan 260
11.5.7. Further development of the process 266
11.6. Voluntary measures of environmental policy 267
11.7. EU environmental management institutions 270
11.7.1. EU directorate-general for the environment 270

12. SUSTAINABLE DEVELOPMENT 279
12.1. Limits to growth 279
12.1.1. Nature of growth and social development 279
12.1.2. Limits to development 284
12.1.3. Beyond the limits 286
12.2. Concept of sustainable development 288
12.3. Formation of the concept of sustainable development 291
12.4. Guiding principles of sustainable development 295
12.5. Ecological footprint 298
12.5.1. Ecological footprint calculation methodology 299
12.5.2. Contemporary society’s ecological footprint 301
12.5.3. How to reduce the ecological footprint 302

1. INTRODUCTION

Understanding of the environment, human-nature relations, pollution impacts and the need to protect environment is a necessity nowadays for any professional as well a question of the general public concern, a driving force for actions of a large number of human activities. The idea of the environment in which the person lives and its quality assurance seems to be simple enough, but actually it has been recognized and, more importantly, as a basis for practical action only during the recent decades. The content of the concept «environmental science» is new, but within a very short time it has developed into an overarching idea crosscutting many activities, a source of social developments affecting the research in other fields of science, technologies, as well as legislation and government institutional framework. There are multiple examples, to mention but a few: environmental legislation, both on a national and international level, environmental protection as one of the main issues of international politics. After all, the identified environmental issues can be assessed at the level of the material substances: for example, taxes for resource recycling, direct investments in environmental protection. Therefore, obviously, the environmental quality has become a major problem for any society's functioning, directly affecting development of the society: it is the main benchmark to determine whether the development is sustainable or not. Thus, the understanding of environmental processes, pollution sources, former, existing and emerging threats caused by environmental pollution and environmental quality degradation is of a great importance to support development and consider it as sustainable. Understanding of environmental pollution, the hazards of exposure is essential.

Figure 1.1. Monument dedicated to Mirzo Ulugbek in Samarkand (Photo by M. Kļaviņš)

Today the concept of sustainable development is not just an opinion on how humanity as such and also each community and society should develop; it is principally a set of opinions about the model of a society that can ensure its own existence. The concept of sustainable development includes physical conditions, political conceptions, the notions of the quality of life or welfare and an optimised influence on the environment to ensure that the resources are equally accessible to all generations. The concept of sustainable development is based on the understanding of three pillars: development, needs of society and needs of the future generations. Within the concept of sustainable development, the concept 'development' includes not only growth (of production, gross national product, welfare) but also the development of social and economic spheres that guarantees the preservation of natural ecosystems and the human living environment. Thus, the

Figure 1.2. Monument dedicated to Mirzo Ulugbek in Rīga (Photo by M. Kļaviņš)

concept of sustainable development is not limited to viewing the short-term processes (to satisfy the current needs) but also aims at ensuring equal opportunities for the next generations.

Development, especially in Western societies, is understood as human domination over nature (illustrated by the phrase 'man – the crown of creation') and the use of its resources for the development of production. This attitude ignores the role of nature and ecosystems in providing for the development of humanity; it also ignores the value of nature per se and that other forms of life and living organisms may have needs and, most importantly, a right to exist.

The main priorities in the development model that dominates in Western societies is economic growth and consumption, the latter being the principal parameter of an individual person's and humanity's welfare. In conformity with this concept, social welfare is the standard of life – the part of income that is used to purchase goods and services. This model of development, based on individual consumption, eventually leads to huge inequality in terms of income and welfare even within a single country (especially because of the cyclic nature of free market economy), to say nothing of the arising differences between different regions of the world. The inevitable differences resulting from such welfare model lead to social tension, military conflicts and social instability.

The consumer society's development based on the constant increase of the need for resources unavoidably leads to the increase in consumption and industrial waste (pollution) and depletion of resources. Due to the growth of production and growth of consumption, the nature of environmental problems over the last decades has changed.

Understanding the character of the development in the so-far existing Western societies was based on the idea of limitless development and growth. Now we have to admit that there are limits to economic growth. These limits are determined by the planet's carrying capacity, accessibility of resources whose amount is limited, and the capacity of the planet's ecosystems to absorb pollution. Although technological progress can, undoubtedly, increase the efficiency of resource use, it is impossible to overcome these development limits. Hence, the development of humanity must guarantee a balance between the planet's ability to sustain human existence and the desired lifestyle.

These concepts are relevant also in respect to development of each specific country and related to a great challenge – the decision in which direction to develop. These challenges are actual also for Uzbekistan and rising of public awareness in respect to urgent environmental issues and sustainable development is of a key importance. The current book aims to contribute to these tasks. Another major task is to summarize the available knowledge about the environment and environmental problems in Uzbekistan, to provide a comprehensive overview for the readers both in Uzbekistan and other countries.

2. UZBEKISTAN: A COUNTRY WITH HISTORY, PRESENT AND FUTURE[1]

2.1. Geographic situation and climate

Republic of Uzbekistan is a doubly landlocked country in Central Asia, comprising 12 provinces, 1 autonomous republic and 1 independent city. The Republic of Uzbekistan is situated in the central part of the Eurasian continent, between the 37° and 45° North latitudes, and the 56° and 73° East longitudes. Its total surface area is 447 400 km^2. Uzbekistan borders Kazakhstan to the North and West, Turkmenistan and Afghanistan to the South, and Tajikistan and Kyrgyzstan in the East (Figure 2.3).

Figure 2.1. Flag of the Republic of Uzbekistan

Figure 2.2. Emblem of the Republic of Uzbekistan

Figure 2.3. Geographic location of Uzbekistan

Uzbekistan is unequally divided into two parts: the plains occupy about three quarters (78.8%) of its territory, while mountains and mountainous valleys constitute the rest (21.2%). The plains, which stretch out from the Northwest to the Southeast, comprise the larger part of the Turan Lowland. This area mainly contains deserts and semi-deserts, including the Karakum Desert – the largest in Central Asia – stretching from the Zeravshan river valley to the Aral

1 The chapter is based on the information from Initial communication of the Republic of Uzbekistan under the United Nations Framework Convention on climate change. 1999, Taskhent

Figure 2.4. Lowland landscape of Uzbekistan (Photo by Adriana Dinu by United Nations Development Programme in Europe and CIS UN Photostream)

Sea. Small mountainous ridges and elevations cross its central part, closed inland drainage basins are common for the landscape in the South. In the South and Southeast of the country the plains gradually transform themselves into ridges and reliefs of the Tien-Shan and Gissar-Allay mountain systems. Between these ridges are located vast valleys with plane-like surfaces (e.g. Tashkent-Golodnosteppe Valley, Fergana and Zeravshan Valleys). The territory of the Republic is characterised by significant variations in altitude. The lowest spot is at the bottom of the Mingbulak depression (12 meters under sea level). Khazret Sultan peak of the Gissar Chain is the highest point, at 4643 m above sea level.

Uzbekistan's climate is strongly influenced by its location between the subtropical and temperate zones. High solar radiation, coupled with the unique features of its surface and air circulation patterns form a continental-type climate. This climate is characterized by seasonal and day-to-night fluctuations in temperature, long, hot, and dry summers, humid springs, and irregular (sometimes cold) winters. Depending on the location, average July temperatures vary from 26 °C in the North, to 30 °C in the South, with the peak temperature around 45-47 °C. Average January temperatures are –8 °C in the North, and 0 °C in the South, with the lowest temperature being –38° (on the Usturt Plateau). Uzbekistan's territory is penetrated by diverse air masses. Transformed Atlantic and Arctic air masses access the vast plains from the North and Northwest. Incursion of tropical air masses and warm southern cyclones can occur across Central Asia, particularly during the cold

Figure 2.5. Mountain landscape of Uzbekistan (Photo by Ole Christian Rousing)

half of the year, provoking intensive warming and abrupt changes in the weather.

Precipitation occurs all year-round, peaking between April and May, or between March and April in higher altitudes. However, precipitation is most common in winter and spring. In spring, snow avalanches are likely and intense rainfall can lead to mudslides. Highly arid, continental, tropical air forms in the summer months, intensely heating the deserts. On the whole, precipitation is minimal (within the range of 80-200 mm a year), yet very unstable, with an annual precipitation variation factor of 0.5. Precipitation can be as much as 300-400 mm a year in the foothills, and 600-800 mm a year on the western and south west slopes of mountain ranges, which are subject to wet air masses. Conspicuously, the Aral Sea does not affect the quantity of precipitation very much, only contributing to slight increases of humidity in the narrow coastal areas.

2.2. Natural resources of Uzbekistan[1]

Natural resources can be divided into several groups, and this classification helps to understand the formation of natural resources, their potential use, the importance and renewal of their reserves. There are real, or identified, and potential natural

[1] The chapter is prepared with contribution of prof. O. Nikodemus

resources. Real natural resources include those that have been identified and evaluated, and whose use is economically grounded. Natural resources includes mineral deposits, soils, timber, as well as protected areas, sand beaches and a microclimate that is suitable for life and recreation. From a historical perspective, this is a dynamic classification since the needs of society are constantly changing; however, this classification is essentially influenced by technological developments. Potential natural resources include those that have not yet been discovered, sufficiently explored or whose use is not economically justified. Among the typical examples are wave and earthquake energy, as well as iceberg freshwater.

It is difficult to establish a border between these groups. For example, the riches of larch timber in Siberian taiga should belong to real natural resources as they constitute a calculated or practically verified quantity. However, this timber becomes a real natural resource only through an economically grounded use of this resource and a traffic infrastructure for the transportation and subsequent processing of timber. A similar approach applies to the valuation of the volume of water in Greenland's glaciers, the heat released from the active zone of the Atlantic volcanic ridge, or natural building material from Vesuvius. If we subtract the costs of building roads and creating infrastructure from the potential value of the resources, it is evident that these resources can be classified only as potential resources.

Traditionally, natural resources are classified according to their accessible quantity and rate of the substance turnover cycle:

- inexhaustible resources,
- conditionally inexhaustible resources,
- exhaustible – partially renewable resources,
- exhaustible – non-renewable resources (Figure 2.6).

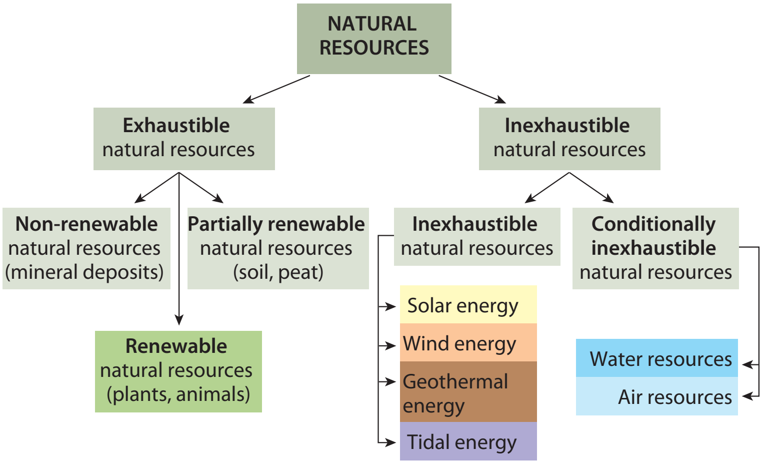


Figure 2.6. Classification of natural resources

It must be noted that even this classification is conditional and the belonging of some natural resources to one or another group may be reconsidered; classifications in popular publications and scientific research can also demonstrate essential differences. Inexhaustible natural resources are the resources whose reserves are not depleted by use, for example, solar energy, wind energy and heat of the Earth's interior. Water resources have long been regarded to be inexhaustible natural resources; however, now many would class them as conditionally inexhaustible or partially renewable resources, considering the particular importance of freshwater for sustaining life and its increasing consumption in the world.

In dividing resources into renewable and non-renewable, it is important to consider the time necessary for the used natural products to be replaced by new ones. It is assumed that it takes several generations for the renewable natural resources to be replaced by other resources. Such are, for example, timber, game animals, fish. Non-renewable resources can never be renewed, for example, fossil fuels (oil and coal) and metallic ores. It is necessary to determine the period of renewal since some resources are renewed over a very long time. Oil or coal has formed over millions of years, which is thousands of times slower than their human consumption rate.

The inclusion of some natural resources among renewable resources lacks justification. For example, resources of the sea (fish, crustaceans) were long considered as exhaustible renewable natural resources. At the turn of the 20th century, the per capita consumption of fish was ~16 kilograms. For many peoples fish and other seafood are their principal daily sustenance. It has been calculated that the total admissible annual harvest of fish and other sea animals in the world amounts to 85 million tons. However, the figure was ignored until fishing exceeded the species' replenishment rate. 47-50% of fish and other populations of sea animals have decreased so rapidly that their natural replenishment is nearly impossible; 15-18% of populations are potentially endangered; 9-10% have decreased but their natural replenishment is possible; 21% are moderately exploited, while only 4% of populations have not been affected.

Uzbekistan is rich in natural resources. Resources of natural gas covers local needs and the extraction of gas in 2005 reached 60 billions m^3. Also resources of oil have industrial importance. Ore mining is of major importance for national economy. The gold resources are evaluated to be 2100 tons, but this amount can reach 3500 tons. The yearly mining of gold reaches 80-85 tons (~3% of the global production). Uzbekistan also has significant resources of polymetallic ores.

One of the most important natural resources is agricultural land and soil – the biologically active upper layer of land with a unique property – fertility. Soil development is an extended, gradual and very complex process. Soil is commonly understood as the uppermost layer of the Earth's crust formed by mineral particles, organic substances, water, air and living organisms. Soil is the contact and interaction zone for the Earth, air and water, and the habitat for most of the biosphere.

Agrarian land can be divided into three categories: irrigated land, dry land, and natural pasture. The Republic's State Forest Reserve accounts for about 3.2% of its total surface area (444 600 km^2). Uzbekistan's forests can be divided into sand-desert, wetland and valley, and mountainous forests; bushes and shrubs also occupy a significant area. The Republic's State Forest Reserve accounts for about 80 thousand square kilometres, some 85% of which lies in the sand zone, 13% in the mountainous zone, and only 2% in wetland and valleys.

As solar radiation is abundant, the only factor inhibiting utilization of agrarian land is a shortage of water resources. Thus, irrigated farming is the basis of agricultural production. Most arable land is irrigated, and only a minor portion of this land is non-irrigated land. The climate in Uzbekistan is favourable for growing crops that thrive in temperate or tropical zones, particularly cotton. Indeed, cotton is its major crop. However, grains, rice and potatoes are also cultivated on irrigated land. Sometimes insufficient warmth in the northern areas can hinder crop ripening. Harsh weather (i.e. late-spring and early-fall frosts, draughts, high temperatures) and

Figure 2.7. Overgrazed foothills in southern Uzbekistan (Photo by Adriana Dinu by United Nations Development Programme in Europe and CIS UN)

pollution in a number of regions have limited the full use of agrarian land resources. Besides cotton, cereals, gardens, and vineyards are planted in the foothills. Astrakhan sheep and camels are bred on vast desert and semi-desert areas. Only 20% of the total area for natural pasture lies in the foothills and the mountains. The saline lands occupy 174 800 km^2 of the area of the Republic, 241 000 hectares of which are extremely saline. The processes of salinization are progressing in Karakalpakstan, as well as in Bukhara and Syr Darya regions. The territories are subject to irrigation, and wind erosion also takes place. During the last 20-30 years the humus content in soil (the main indicator of soil fertility) has been reduced by 30-50%. The soils with very low humus content occupy about 40% of the whole irrigated territory.

Desertification is a loss of natural vegetation which causes a rapid decrease in soil fertility and an eventual total extinction of the soil cover due to the soil erosion. This process involves changes in the soil moisture regime, and soil gets salinised and compacted. It is commonly believed that desertification is most characteristic for desert and temperate desert zones. Regular burning of savannas ranks among the major desertification causes. Natural fires are characteristic of savannas; however, nowadays most of them are consciously started by humans. The burning of vast grass and shrubland territories has affected soils in savannas, they are often depleted, and fire in the regions adjoining deserts and temperate deserts has facilitated the advance of sands.

Figure 2.8. Soil with high salinity (This photo is part of IFPRI's Economics of Land Degradation project. Photographer: Milo Mitchell)

2.3. Biological resources

Location of the Uzbekistan in Central Asia and local climatic conditions determines presence of diverse groups of ecosystems[1]:

1. Desert ecosystems of plains are common for aeloian and alluvial plains and often extends over territories with increased salinity of soils;
2. Foothill deserts and steppe covers ~2/3 of the foothill territories;
3. River and river delta eocsystems covers river bank territories and significant part of areas in basins of Amu Darya, Syr Darya, Chirchik and are covered with an abundant vegetation;
4. Wetland ecosystems covers ~700 000 ha;
5. Mountainous ecosystems with a common forest vegetation

Biological natural resources include vegetable and animal life. Uzbekistan is home to 27 000 specific species of flora and fauna.

Vegetation. Natural flora are represented by almost 4800 species of vascular plants, which belong to 115 families, the most common of which are compositae (570 species); legumes (almost 440 species), and cereals (260 species). This complex and diverse system of vegetation is specific feature of Uzbekistan's climatic and soil. On the plains, desert types of vegetation are formed: saxaul (haloxylon), sand acacia, saltwort, wormwood (absinthe), and sand sedge. The total amount of biomass in the deserts is estimated at 50-60 metric centners per hectare. Biological productivity in the desert is rather low, confined mostly to cattle breeding. Along the riverbanks are tugais and wetland forests where hygrophilous trees, bushes and grass grow, as well as turanga, loeaster, tamarisk, willow, malt, cane, reed, and dog-bane. Some 500 species of wild plants for medicinal, food and raw materials are cultivated in the Republic. However, only 45 of these are commercially used, including dog-rose, rhubarb, St. John's wort, cumin, oregano, bayberry, sage, and malt. In the forests, the main species include: saxaul, kamdym, saltwort (deserts); almond tree eltas, turanga, loeaster, tamarisk (wetlands and river); juniper and pistachio trees (mountains). Forests are of great value and fulfil protective, sanitary and hygienic functions. As such, they belong to and are protected by the State.

The animal world. Of 15 000 species of wild animals, the vertebrates are represented by 5 classes, which include 664 different species: birds (424); mammals (97); fish (83); reptiles (59); and amphibians (3). Some 53 of these species are endemic to the Republic. The fauna in the desert belt is diverse. Reptiles include lizards (toad

---

[1] Первое Национальное сообщение Республики Узбекистан по рамочной конвенции ООН об изменении климата. Ташкент 1999. – 110 с.; Второе национальное сообщение РУз по рамочной конвенции ООН об изменении климата. Ташкент 2008. – 205 с.

agama, monitor lizard, gecko) and snakes (viper, Central Asian cobra). Of the large mammals, goitred gazelle (Middle Asian gazel) and 'saigak' are particularly important to protect. Jackals, wild boar, honey badger, wolves, foxes, porcupines, badgers, and hedgehogs dwell in the plains and foothill areas. The rich diversity of bird life includes eagles, jackdaws, and kites. Many species common to mountainous areas of Central Asia also dwell in Uzbekistan's Alpine zones: the Siberian goat, snow leopard, mountain turkey and others.

Figure 2.9. *Tulipa turkestanica* in Uzbekistan in Nuratau-Kyzylkum biosphere reserve (Photo by Adriana Dinu by United Nations Development Programme in Europe and CIS UN)

Figure 2.10. Bukhara deer in the tugai forest (Photo by Phillip Edwards)

2.4. Natural ecosystems

Given these natural and climatic conditions, a number of different natural ecosystems have evolved on the territory of Uzbekistan: the desert ecosystems of the plains; ecosystems in the foothill semi-deserts and steppes; river and coastal ecosystems; wetland and delta zone ecosystems, and mountainous ecosystems. Each contains a complex system of natural elements that shape the development and health of the above specified flora and fauna. **The desert ecosystems of the plains** are found in the Kyzylkum Desert, Ust'urt plateau, Karshinsky Steppe, in the south of the Republic and the Ferghana Valley. Geologically, desert territories are divided into sand, brackish, clay and rocky (gypsum) soils. Desert ecosystems are the main dwelling area of rare and endangered animal species in the Republic. Sand deserts occupy 27% of the plains. The Kyzylkum, Sundukli, and Kattakum are the largest areas of sand tracts. Rocky desert is typical of the Ust'urt plateau, part of the Kyzylkum Desert, as well as along the southern foothills. Saline soil deserts are found in the Ust'urt plateau and its slopes, in the inland hollows and present delta of the Amu Darya River. The characteristics of these deserts are high salt concentrations in the upper soil layers, a constant humidity level and temporary water reservoirs. Clay deserts are located in the clay and **loess** deposits in the basin of the Kashradarya River, in Dalverzin and in the Golodnaya Steppes.

Foothill semi-deserts and steppes are found in the foothill zone 800-1200 m above sea level, and a 30-50 km strip that encompasses the mountainous ranges. They account for around two-thirds of the mountainous territory of the Republic. **River and coastal ecosystems** are in the plains of the Amu Darya and Syr Darya River valleys and downstream areas of the Zeravshan River and the Surkhan Darya River. Here, there are three main types of ecosystems: tugai, weed thickets, and rivers and open shoals. Tugai tracts are preserved in narrow strips or islands in the Amu Darya River and its delta. They can also be found in the Syr Darya, Surkhan Darya, Zeravshan, and Chirchik River valleys. The rivers and open shoals are home to many rare and endangered animal species. **Wetland areas** (inland waterways and marshes) can be divided into natural and anthropogenic ecosystems. They are similar to river and coastal ecosystems, except for their larger water surface area and higher humidification. Natural wetland areas are located in the Amu Darya River delta, occupying approximately 700 thousand hectares. As water in-flow to the delta declined, shifting the coastal outlay of the Aral Sea, numerous natural freshwater lakes disappeared, tugai areas decreased two-fold, and reed areas decreased six-fold. Only in recent years, as inflow of collected drainage water has slowly increased, have some lake ecosystems recovered. Anthropogenic wetlands are artificial water reservoirs and overflow lakes. The Aydar-Arnasai lake system, Dengizkul, Karakir, and Solyonoe Lakes are the vastest of these.

Mountain ecosystems occupy areas of certain inclines, soil, moisture, and slope conditions. Mountainous steppes are found at heights of 2000-2600 meters above sea level. Deciduous forests grow at the heights between 1000 and 2500-2800 meters above sea level. The largest tracts of deciduous forest are concentrated in the Western Tian-Shan (Ugam, Pskem, Chatkal, and Fergana mountain ranges), and the Pamir-Alay (Gissar mountain range). Walnut, plane, and persimmon trees grow in relict forests. In mountainous areas, at heights of 1400-3000 meters above sea level, juniper forests grow. Sub-alpine and alpine meadows are found at heights between 2700 and 3700 meters above sea level.

References

Initial communication of the Republic of Uzbekistan under the United Nations Framework Convention on climate change. 1999, Taskhent

Атлас Узбекской ССР. Ч. 1. – М-Ташкент ГУГК, 1982. – 124 с.

Окружающая среда и безопасность в бассейне Амударьи. ЮНЕП, ПРООН, ЕЭК ООН, ОБСЕ, РЭЦ, НАТО. 2011. – 11 с. Accessible: *www.unep.org.*

Первое Национальное сообщение Республики Узбекистан по рамочной конвенции ООН об изменении климата. Ташкент 1999. – 110 с.; Второе национальное сообщение РУз по рамочной конвенции ООН об изменении климата. Ташкент 2008. – 205 с.

Национальный доклад о состоянии окружающей среды и использовании природных ресурсов в Республике Узбекистан (1988-2007). Госкомприроды. Ташкент, 2008. – 298 с. Accessible: *www.econews.uz.*

Экологический обзор Узбекистана, основанный на индикаторах. ПРООН, Госкомприроды РУз. Ташкент 2008. – 88 с.

Central Asia Atlas of natural resources. ADB. 2009. – 173 с.

Азизов А. А. Водные ресурсы Центральной Азии – проблемы безопасности и управления. Сб. научных трудов «Водохранилища, чрезвычайные ситуации и проблемы устойчивости. МВССО РУз, НУУз. Ташкент 2004. – стр. 32-42.

3. WATER RESOURCES OF UZBEKISTAN

«Water is not a commercial product like any other but, rather, a heritage which must be protected, defended and treated as such»[1]

3.1. Hydrological cycle

Water is a renewable natural resource that sustains life on the Earth. Water is the most important chemical substance for the existence of human beings and all other species. Only a minor amount of the global water resources is available for a human consumption.

Deterioration of the freshwater quality and depletion of its resources is becoming one of the major problems of society in the 21st century. In 2005, good quality drinking water was not available to two billion of the world's population. According to the UN prognosis, 2.8 billion people in 48 countries will suffer from the shortage of freshwater by 2025; 40 of these countries are in central Asia (including Uzbekistan), northern Africa and the Sahel zone in Africa. For now, the international society does not have a solution to this problem, and a chronic freshwater deficit in 2050 is expected to affect as many as four billion people.

Although the Earth's freshwater resources are huge, many of them are not easily accessible for a variety of reasons (situated high up in the mountains or deep underground), or their quality is not suitable for human consumption. However, availability of water has already caused conflicts between people and countries alike. Experts warn that in the future water problems can create conflicts in central Asia, among Turkey, Syria and Iraq if Turkey builds dams on the Tigris and the Euphrates. In Africa, battles are going on for the waters of the Niger, in Asia for the Mekong, the Indus and the Ganges.

The use of water resources differs from country to country based on the level of development of the country and accessibility of water resources. In economically developed countries the average daily water consumption per person is 200-800 litres, while in developing countries it will hardly exceed 60-150 litres per day.

[1] «Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy» or EU Water Framework Directive

Freshwater has a variety of uses. According to the UN data, the household use of water accounts for 12% of water consumption, 8% is consumed by the power sector and industry, and agriculture uses nearly 70%. In agriculture, water is used for the daily intake of livestock, watering and irrigation of fields. For a better harvest, farmers have turned to improved irrigation methods in many places. In Spain, for example, 14% of irrigated agricultural lands provide over 60% of the total agricultural produce. Because of the irrigation of agricultural lands, surface water resources are running short in certain places, groundwater stores are being depleted, and salt-water intrusion would make freshwater unsuitable for human consumption. Climate change and drier summers in central Asia and elsewhere in the world have increased the use of water resources; therefore, water now has to be imported to the places which never previously have suffered from water shortage. Scientists consider that the pledge of the EU countries to increase the amount of biofuel up to 10% of the total amount of vehicular fuel by 2020 will result in a substantial increase in water consumption for agricultural needs.

Natural waters are categorized according to their overall level of mineralization (the proportion of mineral substances dissolved in water). The main types of water are the following: freshwater (its overall concentration of salts is up to 1 g/l), brackish water (1-10 g/l), saline water (10-35 g/l) and brine (35 g/l and more).

Freshwater makes a small part of all the water on the Earth – approximately 3%. Two thirds of freshwater is accumulated as ice and snow, one third is underground water, while rivers and lakes make just a very small portion of the total volume of freshwater on the Earth (Figure 3.1, Table 3.1).

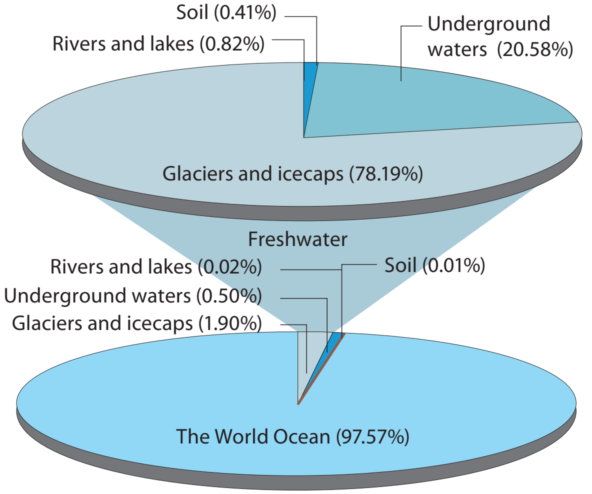


Figure 3.1. Distribution of water resources on the Earth

Table 3.1. Water resources on the Earth

Types of water	*Volume, km³*
The World Ocean	1 338 000 000
Groundwaters	23 900 000
incl. freshwaters	10 530 000
Moisture in the soil	16 500
Glaciers, icecaps, permanent snow	24 064 100
Freshwater lakes	91 000
Saline lakes	85 400
Rivers	2120
Water in the atmosphere	12 900

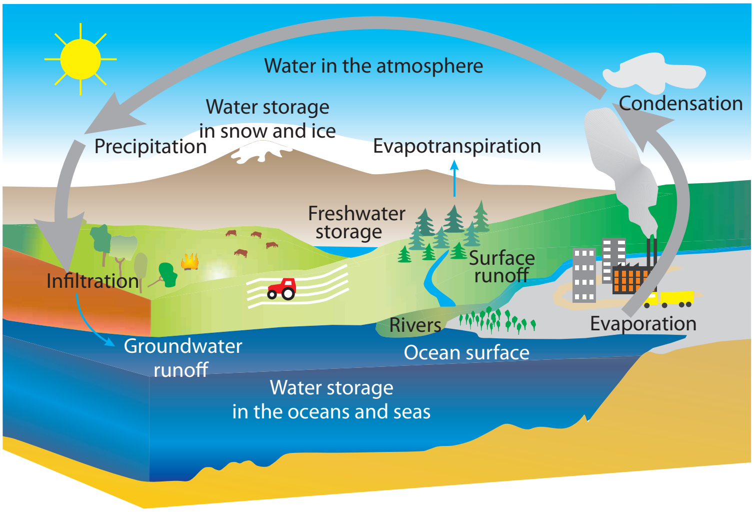


Figure 3.2. Hydrological cycle

The hydrological cycle (Figure 3.2) represents the movement of water on the Earth. Five main sources of water are involved in the hydrological cycle: water in the World Ocean, the atmosphere, glaciers and icecaps, underground and freshwater sources. The hydrological cycle describes the relations among these main sources of water and shows the vital role of the processes of atmospheric evaporation and precipitation fallout for the planet's water balance. The Sun is the main source of energy, driving the global hydrological cycle as it warms the water masses on the Earth's surface, making them evaporate or sublimate: not only from the surfaces of seas and oceans but also from the soil, glaciers, icecaps and the Earth's snow cover. This water evaporates into the atmosphere, where the vapour cools down and condensates. The dust particles in the atmosphere become the condensation centres for water vapours.

The particles formed from the impact of cosmic radiation can also cause water condensation. The condensation processes take place at the upper layers of the atmosphere as well as on the Earth's surface. Precipitation occurs in a variety of forms, including rain, snow and hail. When water evaporates in the atmosphere, it becomes subject to the atmospheric diffusion. Consequently, the water vapour, which is mostly formed above the surface of seas and oceans, can be carried to great distances along with the movement of air masses, until it finally falls out on the continents as well.

Atmospheric precipitation can form a snow cover, it can be assimilated by plants or absorbed in the soil, replenishing the underground water resources. Furthermore, one of the most important water movements is its accumulation in river basins and subsequent surface runoff with rivers. With this, the water cycle is complete. Water can stay in each of the abovementioned environments for a different period of time (water residence time). The duration of a water turnover period depends on the mass of water in the respective environment (for example, oceans contain most of the water mass that undergoes the hydrological cycle) and on the intensity of processes that the water is subject to in the respective environment. The duration of the period in which water completes a full cycle in the oceans and seas is estimated as approximately 4000 years; in lakes – approximately 10 years; for underground waters – from a few weeks to 10 000 years; for glaciers – from 100 to 10 000 years; in the atmosphere – approximately 10 days.

An essential factor for the hydrological cycle is the character of the largest water mass – the World Ocean, particularly its water currents. Currents on the ocean surface are generated by the interaction of wind, the Earth's rotation (the Coriolis force) and thermal factors. The warm water surface currents move a huge amount of heat energy from the tropical zones of the World Ocean to the temperate and arid climatic zones. In effect, the climate becomes much milder in vast areas of dry land. The cold currents, in turn, chill the tropical regions.

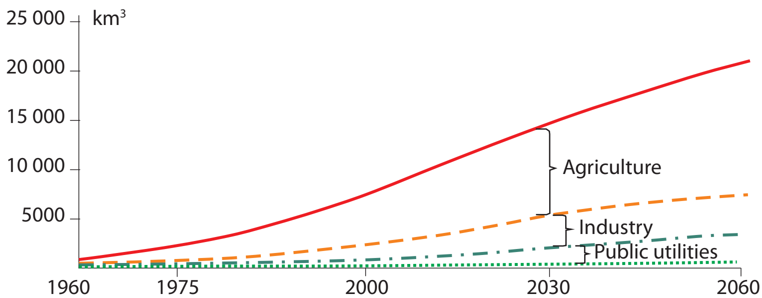


Figure 3.3. Water consumption variability tendencies and forecasts in the main sectors

Water is one of the substances most consumed by human beings – large amounts of water are used for household needs, production, especially in agriculture (Figure 3.3). Humans mostly use high-quality freshwater, but at the same time wastewater is produced as a by-product of human activities, and quite often it does not receive sufficient treatment. The highest water consumption rates in the world are in the following sectors: agriculture (69%), industry (23%), households and services (approx. 8%). Industrial consumption of water is mostly related to various technological processes. Considering the relatively large volumes of water required for industrial production, in many cases the availability of freshwater is the decisive factor for the placement of plants and factories at certain locations. Today, when many other economic factors also come to the fore, most industrial technologies reuse the water for production after proper treatment.

Households consume large amounts of water. It is generally known that a human being, depending on his or her weight and outdoor temperature, for personal consumption needs approx. 40 grams of water per weight kilogram daily. Calculations show that one city dweller in the temperate zone consumes approximately 200-220 litres of water daily. Even more, over 320 litres of water are consumed daily in order to satisfy all the needs of one person, including production of food and commodities and provision of services.

Due to the relatively high precipitation and low evaporation rates, sufficient freshwater supplies are available for people and economies in the Baltic Sea Region. Presently, because of the low population density, the availability of water is not an issue and does not in any way affect the quality of life and economy in the northern part of the Baltic Sea basin. At the same time, in Germany and Poland, the availability of water resources has already become the limiting factor for further development of agriculture. Poland, for example, now uses 18% of the total water runoff in rivers, which is considered to be the maximum amount of water that can be consumed without affecting the water ecosystems. The situation is even more critical in the Mediterranean countries. They do not have enough freshwater, and this deficit is substantially delimiting the development of traditional forms of agriculture. Therefore, these countries are reorienting their national economies to the service sector (mainly tourism).

Agriculture is the industry that consumes the largest amount of water. While in the developed countries this consumption does not exceed 20-25%, in the developing countries up to 80% of water or even more is used for irrigation.

The Baltic Sea is an inland sea. Therefore, its water exchange is limited, it has a relatively low salinity level, it is not deep, it has a large catchment basin and significant freshwater influence. Together these factors make the Baltic Sea particularly sensitive to pollution, for the harmful substances discharged into the sea remain there for relatively long periods of time, contaminate water and living organisms, form sediments.

Even though the water masses involved in the hydrological cycle are huge, human activity affects the flows of water. At present, the amount of water that humans consume is comparable to a substantial part of the runoff of the world's rivers. However, the consumption is expected to exceed the resources of natural water flows in the near future.

3.2. Water resources of Uzbekistan

Figure 3.4. Aral Sea in 2008 (The black line shows the area of the Aral Sea in 1960)

An illustration of the negative impact of human activity on water resource depletion is the desiccation of the Aral Sea (Figure 3.4) caused by the intensive use of water from the major inflow rivers for irrigation (mostly for cotton cultivation). In 1960 the area of the Aral Sea was 67 000 square kilometers, while by 2008 it has shrunk to 17 000 square kilometers. The prognosis for the future of the Aral Sea is bleak: it may completely disappear in a foreseeable future, leaving a vast salt desert in its stead.

Uzbekistan is the main water consumer in the central Asia and it consumes ~47% of the discharge of Amu Darya and Syr Darya[1]. Water resource use and water availability very much differs between countries of Central Asia (Figure 3.5).

Water resource availability of Uzbekistan determines the relief of the country as far as 78.8% of the territory cover plains and the remaining areas are allocated to mountains and their hill slopes. Plains of Uzbekistan are formed by Kyzilkum desert, alluvial plains of Amu Darya River, river deltas and plateau of Ustjurt formed by undulated surfaces of solonchaks. Major part of plains in Uzbekistan can be used for agricultural purposes considering that agricultural activities require irrigation and extensive water supply[2,3]. Also historically water use to cover needs of agricultural activities was common for this country[4]. Major consumer of water resources in the Uzbekistan is agricultural production, consuming 84.2-91.8% of the total water consumption; industrial production consumes 1.8-3%; domestic use is 3-6%; energy production 2-6%.

1 Вода жизненно важный ресурс для будущего Узбекистана. Ташкент, ПРООН. 2007. – 128 с.; www.undp.uz.
2 Чуб В. Е. Изменение климата и его влияние на природно-ресурсный потенциал Республики Узбекистан. Ташкент: Главгидромет РУз, 2000. – 252 с.
3 Атлас Узбекской ССР. Ч.1. – М-Ташкент ГУГК, 1982. – 124 с.
4 Миддендорф А. Ф. Очерки Ферганской долины. С приложением К. Шмидта «Химических исследований почв и воды». Перевод с немецкого В. И. Ковалевского. СПб., 1882. – 489 с.

Table 3.2. Freshwater withdrawal by Country and Sector (top 15 countries, per capita)[1]

Country	Total Freshwater Withdrawal (km³/yr)	Per Capita Withdrawal (m³/p/yr)	Domestic Use (%)	Industrial Use (%)	Agricultural Use (%)
Turkmenistan	24.65	5104	2	1	98
Kazakhstan	35	2360	2	17	82
Uzbekistan	58.34	2194	5	2	93
Guyana	1.64	2187	2	1	98
Hungary	21.03	2082	9	59	32
Azerbaijan	17.25	2051	5	28	68
Kyrgyzstan	10.08	1916	3	3	94
Tajikistan	11.96	1837	4	5	92
USA	477	1600	13	46	41
Suriname	0.67	1489	4	3	93
Iraq	42.7	1482	3	5	92
Canada	44.72	1386	20	69	12
Thailand	82.75	1288	2	2	95
Ecuador	16.98	1283	12	5	82
Australia	24.06	1193	15	10	75

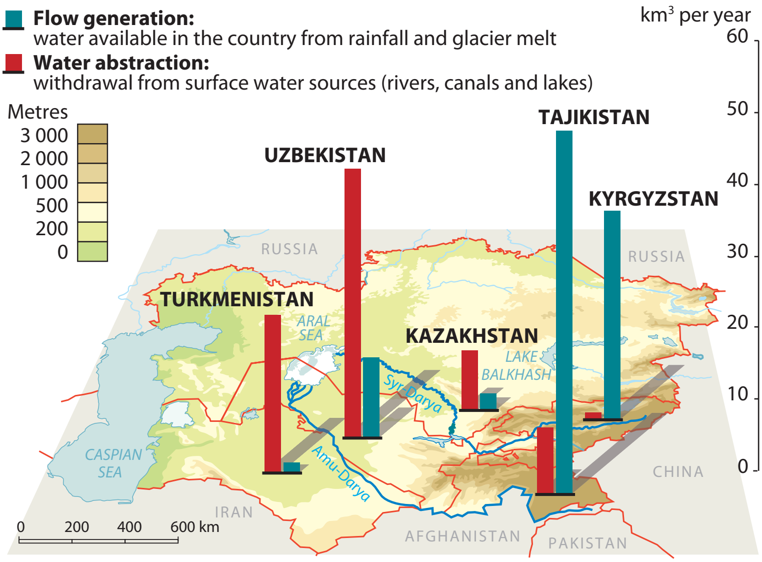


Figure 3.5. Water withdrawal and availability in the Aral Sea basin (Philippe Rekacewicz, UNEP/GRID-Arendal)

[1] Gleick P.H. (2008). «The World's Water 2008-2009». Island Press, Washington, D.C.

The territory of Uzbekistan is an inland basin of the Aral Sea, to which all its rivers and lakes drain. Water resources include natural surface and ground water as well as recycled water. All countries in Central Asia jointly use the surface water of the Aral Sea basin. Water reserves in the lakes of the mountainous area of the Amu Darya River make up 46 km^3, while reserves from the Syr Darya River total 4 km^3 [1]. Excluding the Aral Sea, the total volume of water from the plains is approximately 70 km^3. The volume of ice in the glaciers of the Gissar-Alay area is estimated at 88 km^3, and the glaciers of Pamir-Alay at 465 km^3. River runoff primarily collects in the largest of Central Asia's rivers – the Amu Darya and Syr Darya, which flow into the Aral Sea. The annual volume of river runoff to these rivers is shown in Table 3.4. Uzbekistan is subject to international agreements allocating water use. Uzbekistan is entitled to an average of 43-52 km^3 of water per year. In any given year, water allocations are calculated and adjusted subject to the agreed ratio.

Table 3.4. Water Resources (km^3/year) of the Rivers of the Aral Sea Basin[2,3]

River	*River average long-term volume of runoff*	*Volume of runoff corresponding to 5% cumulative probability*	*Volume of runoff corresponding to 95% cumulative probability*
Amu Darya	78.5	108.4	46.9
Syr Darya	37.9	54.1	21.4

Total number of different streams in Uzbekistan is 17 777 and from them in basin of River Amu Darya are allocated 9930 and for the basin of River Syr Darya are allocated 4926. In the Uzbekistan are >500 lakes, but most of them are small with an area less than 1 km^2 [4]. Lakes usually are located in the river valleys. In the mountainous areas lakes are formed as a result of glacier melting, especially when the discharge possibilities are limited. The number of lakes in mountainous and plain areas is relatively similar (correspondingly 56.5% and 43.5%). Mountainous lakes usually originate from obstruction and glacier-moraine, while lakes located in the plains form from drainage water.

1 Ирригация Узбекистана. Том I, Развитие ирригации в комплексе производительных сил Узбекистана. Ташкент, Из-во «Фан» 1975. – стр. 138-169.

2 Окружающая среда и безопасность в бассейне Амударьи. ЮНЕП, ПРООН, ЕЭК ООН, ОБСЕ, РЭЦ, НАТО. 2011. – 11 с. www.unep.org.

3 Вода жизненно важный ресурс для будущего Узбекистана. Ташкент, ПРООН. 2007. – 128 с.; www.undp.uz.

4 Национальный доклад о состоянии окружающей среды и использовании природных ресурсов в Республике Узбекистан (1988-2007). Госкомприроды. Ташкент, 2008. – 298 с.; www.econews.uz

Much like the Aral Sea basin, Uzbekistan on the whole features an unequal distribution of water resources. The plains contribute very little to river flows. In irrigated zones, these flows are mainly from irrigation canals. But in the upper watershed, the zone of flow formation, there is a well-developed river network. Six percent of the river runoff directly formed on Uzbekistan's territory emanate from the Amu Darya River basin and 15% come from the Syr Darya River basin. However, less than 10% of total runoff are formed on Uzbekistan's territory; the bulk of water resources used in Uzbekistan originate beyond its borders. The natural course of river flow from the Amu Darya and Syr Darya Rivers is greatly distorted by reservoirs, water withdrawal for irrigation, and the discharge of drainage water. All of these break up their hydrodynamic and hydrochemical regimes.

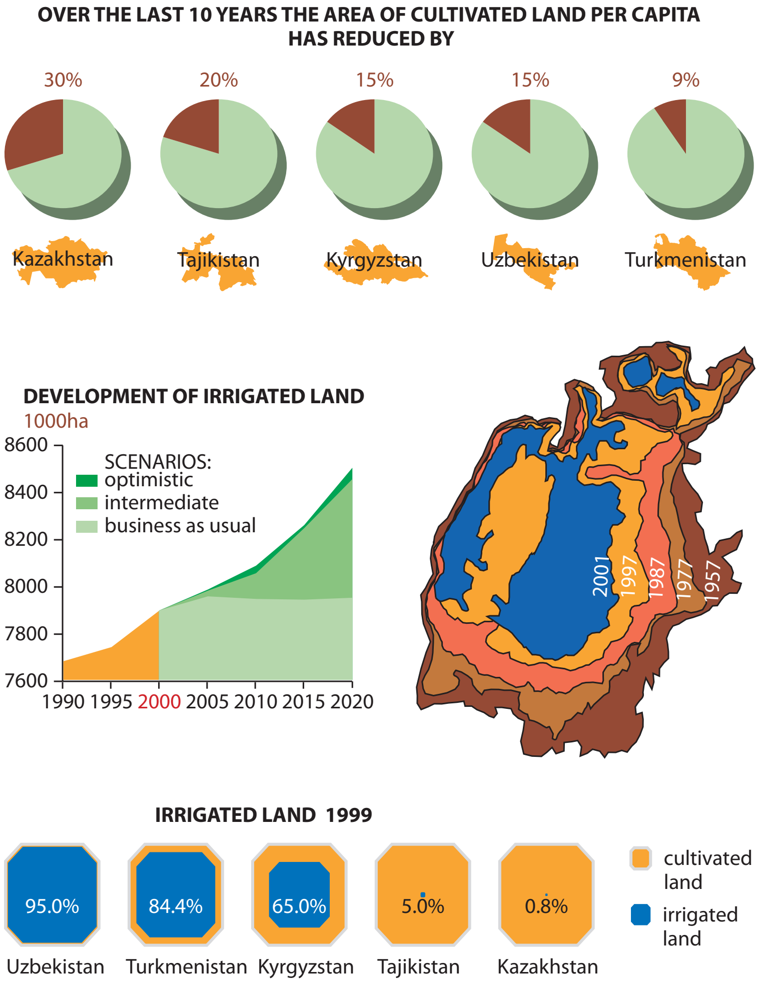


Figure 3.6. Trends of changes of areas of irrigated land in Central Asia countries (I. Atamuradova, V. Yemelin, P. Rekacewicz, UNEP/GRID-Arendal)

The groundwater resources of Uzbekistan are 24 km^3. The ground water of the Aral Sea basin, including the territory of Uzbekistan, is formed from precipitation as well as filtration from water reservoirs, riverbeds, canals, lakes, and irrigated areas. Presently, there are 95 deposits of ground water in the Republic. Recycled water resources include collected drainage and wastewater. While constituting a large share of water resources, at the same time it is a serious source of pollution. The Tuyamuyun, Chardara, Karakum, Charvak, and Andijan reservoirs are the largest artificial water facilities in Uzbekistan. They were built to regulate seasonal river runoff, accumulate water for irrigation periods, as well as to prevent flooding. At the edge of irrigated areas, in natural depressions and reliefs, lakes are formed from water overflow. The lakes of the Arnasay and Sarykamish systems, in their current dimensions, were formed by water drainage from reservoirs. Irrigated farming utilizes more than 90% of the region's available water resources.

The massive expansion of irrigated agriculture in the 1960s–1980s for cotton production has caused major alterations to the runoff regime with well-known consequences for the deltaic ecosystems and the Aral Sea. Today irrigated agriculture accounts for 90% of crop yields and consumes over 92% of the total water intake. About 64% of the population of Uzbekistan live in rural areas and are thus directly or indirectly dependent on irrigated agriculture. In the future the demand for water will grow even more in order to maintain the food security of a rapidly increasing population[1].

3.3. River Amu Darya

The Amu Darya was traditionally known to the Western world from Greek and Roman times as the Oxus and was called the Jayḥūn by the Arabs. The name *Amu* is supposed to come from the medieval city of *Āmul*, in modern Turkmenistan, with *Darya* being the Persian word for «river». Historically Amu Darya's course across the Karakum Desert has gone through several major shifts till to the late 16th century, the Amu Darya emptied into both the Aral and the Caspian Seas, via a large distributary called the Uzboy River. The Uzboy split off from the main channel south of the Amu Darya Delta. Sometimes, the flow through the two branches was more or less equal, but often most of the Amu Darya's flow split to the west

[1] Ирригация Узбекистана. Том I, Развитие ирригации в комплексе производительных сил Узбекистана. Ташкент, Из-во «Фан» 1975. – стр. 138-169.

and flowed into the Caspian. Since the 18th century, the river turned north, flowing into the Aral Sea and the Uzboy River dried up[1].

The Amu Darya River is the largest of the two rivers of Central Asia that feed the Aral Sea with an average annual runoff of 78.5 km^3. The river's total length is 2540 kilometres. It accounts for two thirds of the total water resources in the Aral Sea basin. It is a glacier/snowmelt-fed type of river and the water comes from the high mountains in the south where annual precipitation can be over 1000 mm. Without its mountain water sources, the Amu Darya would not exist, rains in the lowlands through which most of the river flows are rare (throughout most of the steppe, the annual rainfall is about 300 mm). The main flow volume (85%) is formed by the Vakhsh and Pyandj tributaries in the high mountain ranges of the Pamir, Tienshan and Hindukush in Tajikistan and Afghanistan. It drains into the lowland desert plains of Uzbekistan and Turkmenistan. The catchment of the Amu Darya River is 535 000 km^2. Over 1000 km of the river borders with the states of Uzbekistan and Turkmenistan before it enters the Aral Sea. Along the river a significant quantity of water is abstracted for irrigated agriculture.

Figure 3.7. River Amu Darya (*www.flickr.com/photos/joepyrek/3879372758/sizes/o/in/set-72157622084600263/*)

Rainfall and temperature in the Amu Darya basin vary mainly according to topography. Mid-latitude westerlies are the main source of precipitation in the river basin. The precipitation falls mainly as snow during the winter and helps feed the glaciers in the source areas of the Amu Darya, at the highest elevations in the Pamirs

[1] Географический энциклопедический словарь. М.: «Советская энциклопедия» 1989. – 591 с.

and the Hindukush, where temperatures average below freezing in winter and annual precipitation may exceed 1015 mm. Mean monthly temperatures increase and precipitation decreases at lower elevations. In the lower reaches of the Amu Darya, mean annual precipitation is less than 100 mm, with mean July temperatures above 25 °C and mean January temperatures ranging between 0 °C and 10 °C.

Hydrologically, therefore, the Amu Darya basin consists of two units: a mountainous zone of nourishment and a lowland zone of depletion. The Amu Darya's headwaters rise in the mountains of Tajikistan and Afghanistan, among the permanent snows and glaciers of the Pamirs, the Trans-Alay Range to the northwest, and the Hindukush, where elevations range from 5000 to 7000 m. The river's two principal sources, the Vakhsh River and the Panj River, whose tributaries include the Pamir, follow a westerly course.

The Amu Darya's flow increases from March to May, when snow melts on the plains and rainfall increases, and the flow is further augmented in summer as the ice and snow of the mountain ranges melt. The flow gradually abates from September to February. During winter, ice forms along the banks of the river's upper reaches, and its lower sections may freeze completely for more than two months. As the ice floes begin to disperse in February and March, they jam the river downstream, forming a natural dam. These dams sometimes burst catastrophically and cause major flooding. In its upper course the river's flow is stable; in its lower course it is much less so. The river's sediment load is high.

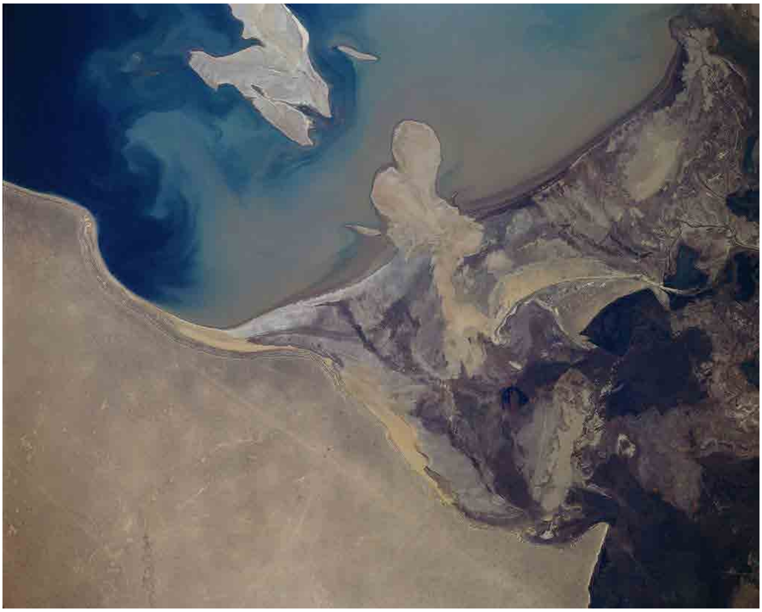


Figure 3.8. Amu Darya delta from space (Image courtesy of Earth Sciences and Image Analysis Laboratory, NASA Johnson Space Center)

Before the 1970s, the Amu Darya branched into a number of tributaries that emptied into the Aral Sea through an extensive delta. However, the Soviet government began diverting massive amounts of water from the river beginning in the 1950s to irrigate cotton and other crops grown in the river's lower basin. The main section of the Karakum Canal was completed in the 1960s to carry water from the Amu Darya at Kerki, Turkmenistan, westward to Mary and Ashgabat. The diversion of water from the Amu Darya for irrigation decreased the amount of water entering the Aral Sea, which consequently began shrinking. Increased irrigation on the hot, dry floodplains of the Amu Darya and in adjacent regions resulted in evaporation that left salt deposits that make the soil infertile. Surface runoff transported these salts into surface waters and increased the salinity of the Amdarya. By the 1990s the discharge of the Amu Darya into the Aral Sea stopped for one to three months in most years. Lakes and bogs dried up in the former Amu Darya delta, now far from the sea's shores, and the wetlands fed by the river shrank to only a tiny percentage of their former size.

It begins with the confluence of the rivers Pyandj and Vakhsh in Tajikistan, and in the upper-reach it forms the border between Tajikistan, Uzbekistan and Afghanistan. From the mountains it flows into the desert lowlands of Turan through Uzbekistan and Turkmenistan and drains into the Aral Sea. Along the main river there are two reservoirs with hydroelectric power stations, representing the main structures for management of water flow and salinity, several distribution points to serve irrigation water needs, main and side inflows, including return flow, and water intake for communal needs.

Next to the quantity of water allocated to the environment, its quality is of equal importance. To conserve the remaining deltaic lakes and semi-natural vegetation to the desired extent, a certain amount of freshwater input is necessary. Water allocated to the environment consisting mainly of drainage. Severe alterations to the hydrological regime of the Amu Darya River over the past 40 years have caused serious degradation of the environment in the whole river basin and especially in river delta and Aral Sea[1]. Desertification processes initiated by the continuous decrease in river flow have significantly changed the ecosystems of the region. The deltaic lakes, pastures and riverine forests have been, and still are, to a large extent, the means of existence for the local human population. Their importance has even increased with the loss of the fishing industry in the Aral Sea. In this respect of major importance

[1] Schluter M., Savitsky A.G., McKinney D.C., Lieth H. (2005) Optimizing long-term water allocation in the Amudarya River delta: a water management model for ecological impact assessment. Environm. Modelling Software 20 529-545

are approaches used for allocation of water resources and regulation of them. Allocation of the Amu Darya and Syr Darya transboundary water resources between the five states of the central Asia is still based on existing quotas of the Soviet times at first covering irrigation water needs. However amongst countries of the region need for adjustments of the water resource management is widely accepted, considering changing needs in agriculture, the demands of the ecosystems in the deltas and littoral of the Aral Sea, effects of climate change, or other physical or socio-economic factors.

3.4. River Syr Darya

Syr Darya with a length of 3019 km is the longest river in Central Asia, but it carries less water than the Amu Darya. Historically river has been called Jaxartes. The Syr Darya is formed by the confluence of the Naryn and Qoradaryo rivers in the eastern Fergana Valley and generally flows northwest until it empties into the Aral Sea.. Watershed of Syr Darya is not clearly defined except in its upper course, where it drains a basin of 462 000 km^2. Most of the Syr Darya's tributaries in the Fergana Valley fail to reach it because they are used fully for irrigation. After leaving the Fergana Valley the river flows northwest, receiving the Ohangaron, Chirchiq, Keles, and Arys rivers on the right. In its middle and lower reaches it follows a meandering course through the eastern outskirts of the Kyzylkum Desert, frequently changing its bed, forming channels that often lose themselves in the sands, and overflowing its low banks at flood. It is fed in its upper mountainous basin mainly by snow and to a lesser extent by glaciers, and high water lasts from March or April to September. The Syr Darya carries a considerable amount of silt, much of which it deposits in the vicinity of Qazaly, Kazakhstan. The river freezes in its lower reaches from December to March.

There are a number of hydroelectric power stations on the Syr Darya and its tributaries, of which the largest are the Farhod (in Uzbekistan), Qayroqqum (Tajikistan), and Shardara (Kazakhstan) stations on the main stream and, in Uzbekistan, the Chorwoq station on the Chirchiq River and the Uchqŭrghon station on the Naryn River. There are also dams in Kazakhstan at Qyzylorda and Qazaly. The Toktogul hydroelectric power station, which was constructed on the Naryn River in the 1970s and expanded in the '80s, regulates the river's flow. As much as 2 000 000 hectares) of land are irrigated by the Syr Darya and its tributaries, with cotton the chief crop in the Fergana Valley and the Syr Darya's middle course and rice in the river's lower reaches.

Figure 3.9.
Syr Darya floodplain (ISS Expedition 25 crew – NASA Earth Observatory)

The diversion of water from the Syr Darya for irrigation contributed to the shrinkage of the Aral Sea in the latter part of the 20th century. By the 1990s the flow of the Syr Darya along its lower reaches was much reduced during the whole year. The gradual retreat of the Aral Sea shoreline and the drying up of the Syr Darya's deltaic region exposed toxic fertilizer and salt residues to the winds, devastating local plant and animal life and causing serious health problems among the human population[1].

Historical legacies and the regional political context are of particular relevance in the Syr Darya basin. Agriculture was initially made possible by the Soviet administration in the early 20th century in Central Asia through the development of intensive irrigation systems to fuel larger-scale cotton cultivation. By the 1960s, the traditional belief in inexhaustible Central Asian water resources had diminished as river flows and ground water reserves were depleted and water and soil quality degraded. In order for the Soviet Union to become self-sufficient, priority for water allocation was given to the cotton production in the Uzbek Soviet Socialist Republic (SSR) and to rice production in the Kazakh SSR, with the Kyrgyz SSR designated as water supplier. Major investments were made in the construction of dams, reservoirs, irrigation canals and other structures to promote and manage the transfer of water from its source in the Kyrgyz mountains to the main growing areas in the Uzbek and Kazakh SSRs. The administrative borders of the Central Asian Republics did not

[1] Оценка региональных рисков в Центральной Азии: реагирование на угрозы в области водной, энергетической и продовольственной безопасности. Программа развития ООН. Региональное бюро по странам Европы и СНГ. ЮНДП. Нью-Йорк. Январь 2009. www.undp.org/rbec

match the natural hydrological borders of the Syr Darya basin and were disregarded in the construction process of irrigation canals and dams. The costs of water management within the upstream SSRs were paid for or subsidized from Soviet central funds and the upstream republics received benefits such as the provision of cheap fuel, electricity and food supplies[1].

Major factors influencing water resource management in Uzbekistan and in general in Central Asia are:

1. Freshwater resources in the Central Asia are naturally limited and unequally distributed with the region and also seasonally;
2. The water consumption in Central Asia and especially in Uzbekistan is permanently growing, but the water supply amount per capita is permanently decreasing;
3. In the region there is a growing human pressures on the water quality due to intensive use of agrochemicals, increase of mining industry, oil and gas production as well as domestic wastes and wastewaters;
4. Global climate change is influencing the water resource availability already now and most probably much more in future;
5. The approaches used for water resource management largely is based on historically accepted approaches and not always do consider recent trends and best practices in the water resource management.

The impacts of climate change most probably will significantly reduce availability of water resources, especially in periods of most intensive irrigation.

The impacts of climate change on the availability of water resources can be associated with:

1. General decrease of water resource availability;
2. Increase of air, temperature, thus increase of evaporation, reduction of precipitation amount, decrease of glacier volume;
3. Intensification of desertification processes;
4. Increase of risks caused by extreme climate events;
5. Reduction of bioproductivity of natural ecosystems.

3.5. The Aral Sea

The Aral Sea is a lake located between Kazakhstan and Uzbekistan. The name can be translated as «Sea of Islands», referring to about 1500 islands that once were present in the Sea. The Aral Sea

[1] Хамраев Н. Р., Ахунди М. Н., Эргашев А. К. Проблемы и перспективы устойчивого развития водохозяйственного сектора государств бассейна Аральского моря. – Ташкент. – 1998. – 85 с.

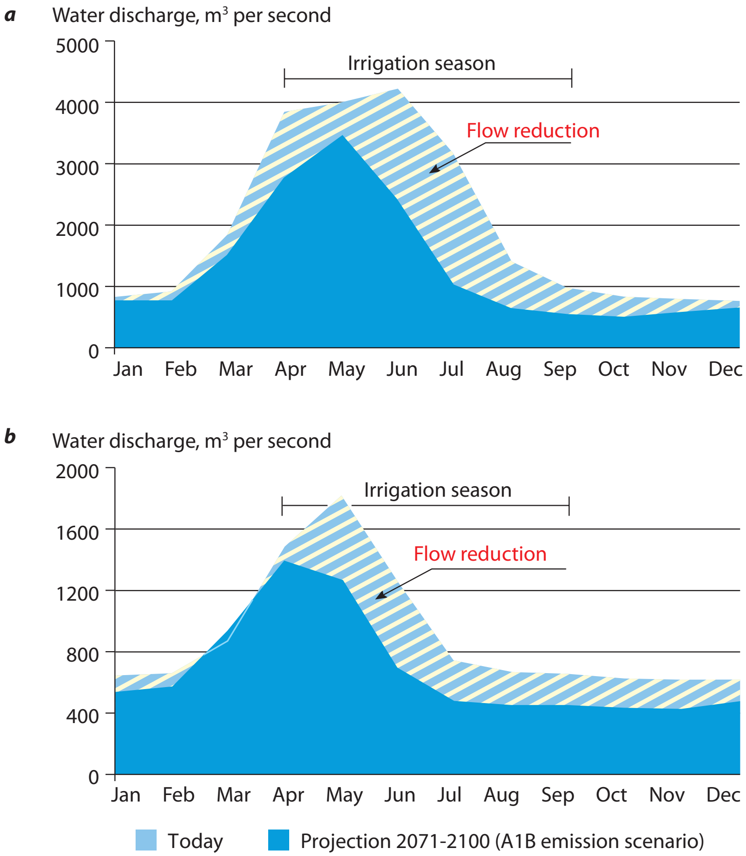


Figure 3.10. Changes of annual discharge of Rivers Amu Darya (***a***) and Syr Darya (***b***) under conditions of changing climate (IPCC, 2007: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M.Tignor and H. L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA)

was formed about 5.5 million years ago. Formerly an area of the Aral Sea was 68 000 km^2 Aral Sea has been steadily shrinking since the 1960s after the rivers that fed it were diverted by Soviet irrigation projects. The shrinking of the Aral Sea has been called «one of the planet's worst environmental disasters».

Prior to the drying of the Aral Sea, its volume was 1064 km^3, rivers Amu Darya and Syr Darya supplied yearly 56 km^3, but atmospheric precipitations (annual precipitation ranges between 90-100 mm) added 9 km^3, however the evaporation amounted on average 65 km^3 per year. The maximal depth of the Sea was 69-66 m. Presently the maximum depth of the North Aral Sea is 42 m (as of 2008). Irrigation resulted in a sharp decline of the water in-flow to the Aral Sea, and, consequently, a drop in the Sea's water level, shrinking of its surface area, and an increase in salinity. By 1994, the Sea's total surface dropped to 31 700 km^2. During 20th century the sea's surface has decreased by 75% and its volume by 90%. Salt marsh and salty shifting sand areas formed and became sources of aeolian transfer of sand and salt onto the contiguous territories. Prior to 1992, salinity averaged 9-11%; but by 1992, salinity increased to 35%, equal with the salinity of the World's Oceans. Under such conditions, the Sea's functions to provide needed ecosystem services are limited. As a result, the sea is divided into two separate water bodies: the shallow Small Aral Sea in the north and the southern Large Aral Sea. The shallow eastern basin and the deeper western part of the Large Aral Sea are currently connected by a narrow canal. This canal will dry up in the case of continuing sea level decrease[1].

Figure 3.11. Aral Sea continues to shrink (2009) (Jesse Allen – NASA Earth Observatory)

Aral Sea played a key role in the economy of the region. Annual fish harvesting was approximately 400-500 thousand metric centners, and the volume of cargo turnover was ~250 000 tons. The Aral crisis is one of the most significant ecological disasters. About 35 million people including a considerable part of the Uzbekistan's

1 Johansson O., Aimbetov I., Jarsjo J. (2009) Variation of groundwater salinity in the partially irrigated Amudarya River delta, Uzbekistan. J. Mar. System, 76, 287-295

population experience its impact. Increased water scarcity in the region has created social problems in Karakalpakstan and the Khorezm Province. The present ecological situation has negatively affected 1.5 million people. The region's once-prosperous fishing industry has been essentially destroyed, bringing unemployment and economic hardship. The Aral Sea region is also heavily polluted, with consequent serious public health problems. The retreat of the sea has reportedly also caused local climate change, with summers becoming hotter and drier, and winters colder and longer.

Figure 3.12. Ship of the Aral Sea fleet (Photo Staecker – Own work)

Figure 3.13. Aralsk harbor (Photo Staecker – Own work)

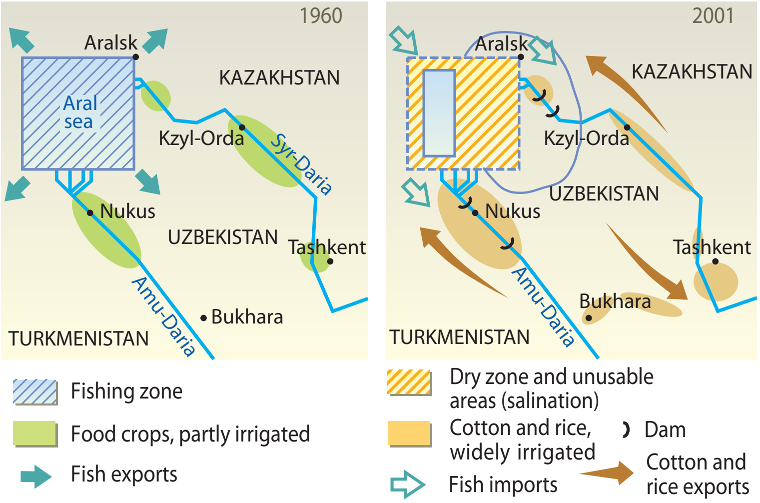


Figure 3.14. The socio-economic impacts of the shrinking of the Aral Sea (Philippe Rekacewicz, UNEP/GRID-Arenda)

Global warming that has already occurred has only aggravated the complex ecological situation in this region. The ecosystems of the Aral Sea and the river deltas feeding into it have been nearly destroyed, not least because of the much higher salinity. The receding sea has left huge plains covered with salt and toxic chemicals – the results of weapons testing, industrial projects, and pesticides and fertilizer runoff – which are picked up and carried away by the wind as toxic dust and spread to the surrounding area. The land around the Aral Sea is heavily polluted, and the people living in the area are suffering from a lack of fresh water and health problems, including high rates of certain forms of cancer and lung diseases. Respiratory illnesses, including tuberculosis (most of which is drug resistant) and cancer, digestive disorders, anaemia, and infectious diseases are common ailments in the region. Liver, kidney, and eye problems can also be attributed to the toxic dust storms. Health concerns associated with the region are a cause for an unusually high fatality rate amongst vulnerable parts of the population. The child mortality rate is 75 in every 1000 newborns and maternity death is 12 in every 1000 women. Crops in the region are destroyed by salt being deposited onto the land. Vast salt plains exposed by the shrinking Aral have produced dust storms, making regional winters colder and summers hotter.

References

Атлас Узбекской ССР. Ч. 1. – М-Ташкент ГУГК, 1982. – 124 с.

Ирригация Узбекистана. Том I, Развитие ирригации в комплексе производительных сил Узбекистана. Ташкент, Из-во «Фан» 1975. – стр. 138-169.

Окружающая среда и безопасность в бассейне Амударьи. ЮНЕП, ПРООН, ЕЭК ООН, ОБСЕ, РЭЦ, НАТО. 2011. – 11 с. Accessible: *www.unep.org*.

Вода жизненно важный ресурс для будущего Узбекистана. Ташкент, ПРООН. 2007. – 128 с. Accessible: *www.undp.uz*.

Большое Аральское море в начале XXI века. Москва: Наука 2012. – 229 с.

Первое Национальное сообщение Республики Узбекистан по рамочной конвенции ООН об изменении климата. Ташкент 1999. – 110 с.; Второе национальное сообщение РУз по рамочной конвенции ООН об изменении климата. Ташкент 2008. – 205 с.

Национальный доклад о состоянии окружающей среды и использовании природных ресурсов в Республике Узбекистан (1988-2007). Госкомприроды. Ташкент, 2008. – 298 с. Accessible: *www.econews.uz*.

Экологический обзор Узбекистана, основанный на индикаторах. ПРООН, Госкомприроды РУз. Ташкент 2008. – 88 с.

Central Asia Atlas of natural resources. ADB. 2009. – 173 с.

Региональный обзор: «Проблемы водоснабжения и канализации в странах Центральной Азии и Южного Кавказа». «Global Water Partnership in Central Asia and Caucasus». August. 2009. – 92 с.

Азизов А. А. Водные ресурсы Центральной Азии – проблемы безопасности и управления. Сб. научных трудов «Водохранилища, чрезвычайные ситуации и проблемы устойчивости. МВССО РУз, НУУз. Ташкент 2004. – стр.32-42.

Хамраев Н. Р., Ахунди М. Н., Эргашев А. К. Проблемы и перспективы устойчивого развития водохозяйственного сектора государств бассейна Аральского моря. – Ташкент. – 1998. – 85 с.

Water a shared responsibility// The United Nations World Water Development, Report 2. UNESCO/ 2006/ pp. 584.

Диагностический доклад для подготовки региональной стратегии рационального и эффективного использования водных ресурсов Центральной Азии. Специальная программа ООН для экономик Центральной Азии. Проектная Рабочая Группа по энергетическим и водным ресурсам. ООН. 2002. 54 с.

Блинов Л. К. Гидрохимия Аральского моря. Л.: Гидрометеоиздат, 1956. – 152 с. Micklin P. (2007). «The Aral Sea Disaster». *Annual Review of Earth and Planetary Sciences* 35 (4): 47-72.

Amu Darya basin network. Accessible: *amudaryabasin.net*.

Чуб В. Е. Изменение климата и его влияние на природно-ресурсный потенциал Республики Узбекистан. Ташкент: Главгидромет РУз, 2000. – 252 с.

Окружающая среда и безопасность в бассейне Амударьи. ЮНЕП, ПРООН, ЕЭК ООН, ОБСЕ, РЭЦ, НАТО. 2011. – 11 с. Accessible: *www.unep.org*.

Вода жизненно важный ресурс для будущего Узбекистана. Ташкент, ПРООН. 2007. – 128 с. Accessible: *www.undp.uz*.

Большое Аральское море в начале XXI века. Москва: Наука 2012. – 229 с.

Наши воды: возьмемся за руки минуя границы. Первая оценка состояния трансграничных рек, озер и подземных вод. ЕЭК, ООН, Нью-Йорк и Женева, 2007. – 377 с. Accessible: *www.unece.org/env/water/*.

Первое Национальное сообщение Республики Узбекистан по рамочной конвенции ООН об изменении климата. Ташкент 1999. – 110 с.; Второе национальное сообщение РУз по рамочной конвенции ООН об изменении климата. Ташкент 2008. – 205 с.

Национальный доклад о состоянии окружающей среды и использовании природных ресурсов в Республике Узбекистан (1988-2007). Госкомприроды. Ташкент, 2008. – 298 с. Accessible: *www.econews.uz*.

Экологический обзор Узбекистана, основанный на индикаторах. ПРООН, Госкомприроды РУз. Ташкент 2008. – 88 с.

Central Asia Atlas of natural resources. ADB. 2009. – 173 с.

Азизов А. А. Водные ресурсы Центральной Азии – проблемы безопасности и управления. Сб. научных трудов «Водохранилища, чрезвычайные ситуации и проблемы устойчивости. МВССО РУз, НУУз. Ташкент 2004. – стр. 32-42.

Традиционные знания в области землепользования в странах Центральной Азии: Информационный сборник/Под общей редакцией Г. Б. Бектуровой и О. А. Романовой – Алматы: S-Принт, 2007. – 104 с.

4. HUMANS AND THE ENVIRONMENT

4.1. Systems of the Earth: the lithosphere, hydrosphere, atmosphere and biosphere

4.1.1. Environmental science – a science of environmental systems

Everything is interrelated. All elements and processes in both organic and inorganic nature are interrelated – they influence each other in myriads of ways. However, among these innumerable interconnections, there are groups of individual elements or processes that can be marked out as more closely related, for example, clockwork parts, computer microchip components or members of one family. Each of these aggregates of elements has specific functions: clock shows time, computer processes information, family raises new members of society.

Figure 4.1. Earth viewed from space

An aggregate of interconnected elements that performs specific functions is called a system (from the Greek word *systema*, which means ‘a whole consisting of parts’). System theory classifies systems by their level of complexity. The natural systems comprising the Earth and everything on it are extremely complicated systems.

The Sun and its planets formed from the condensation of gas and dust clouds in the interstellar space about 4.6 billion years ago. The Earth functions by means of specific systems (spheres) – the atmosphere, hydrosphere and lithosphere – and the flows of substances and energy among these systems. The spheres of the Earth differ with respect to their composition, mass and processes taking place in them (Table 4.1), i.e. the processes of exchange of substances composing each sphere (e.g., water evaporation, condensation and runoff cycle) (Table 4.2).

Systems can be open or closed. In an open system, the flows of substances and energy are not confined. Ocean is an open system with respect to the Earth’s combined mass of water – the hydrosphere. The Earth, on the one hand, can be considered a closed system with respect to the flows of substances (the Earth’s mass is increased by a relatively small mass of falling meteorites, and a relatively small mass of substances leaves the upper layers of the atmosphere and dissipates into outer space); on the other hand, it is an open system with respect to the flows of energy (the Earth receives energy from the Sun and reflects part of the received energy into outer space). A characteristic feature of systems is their capability to react on various influences – feedback, which can be positive or negative. This feedback or counteraction is auto-regulative – it stabilises the system, maintains it in a relatively constant state. The feedback is positive when an impact on the system results in a further enhancement of the system's activity.

Table 4.1. Main structural elements of the Earth

	Chemical elements	*Aggregative state*
Atmosphere	N_2, O_2, H_2O, CO_2, Ar	Gaseous
Hydrosphere	H_2O (water, ice), substances dissolved in water (Na^+, Ca^{+2}, Cl^-)	Liquid, solid
Biosphere	Organic substances, H_2O	Liquid, solid
Lithosphere		
Crust	Silicates, carbonates, sulphides, oxides	Solid
Mantle	Silicates (olivine, pyroxene)	Solid
Core	Iron and nickel	Fluid (inner core – solid)

Table 4.2. Mass of the Earth's main components and the turnover period of substances in them

	Mass, kg	*Turnover period, years*
Biosphere	4.2×10^{15}	60
Atmosphere	5.2×10^{18}	0.2
Hydrosphere	1.4×10^{21}	1600
Crust	2.4×10^{22}	$> 3 \times 10^{7}$
Mantle	4.0×10^{24}	$> 10^{8}$
Core	1.9×10^{24}	Permanent

A typical example of negative feedback in an inanimate, technical system is Watt's Regulator (Figure 4.2). When the fly-ball rod rotation speed increases, the centrifugal force makes the system close the steam valve to the cylinder, thus ensuring that the engine always runs at the same speed.

Another factor that significantly influences the processes taking place on the Earth is the global sum of all living organisms – the biosphere. Life originated about 1.6 billion years after the formation of the Earth, and since then it has been substantially influencing the development of our planet. A great number of species of organisms have developed, flourished and disappeared since the times of the origination of life. Human beings have evolved during a very short period of the Earth's development process, and it is understandable that from the human perspective it appears as the most significant period. Hence, an understanding of how we can affect the environment around us is also significant. Nowadays human activities can influence the processes taking place on the Earth. Life affects the Earth's combined mass of water – the hydrosphere – troposphere and the upper layer of the Earth's crust.

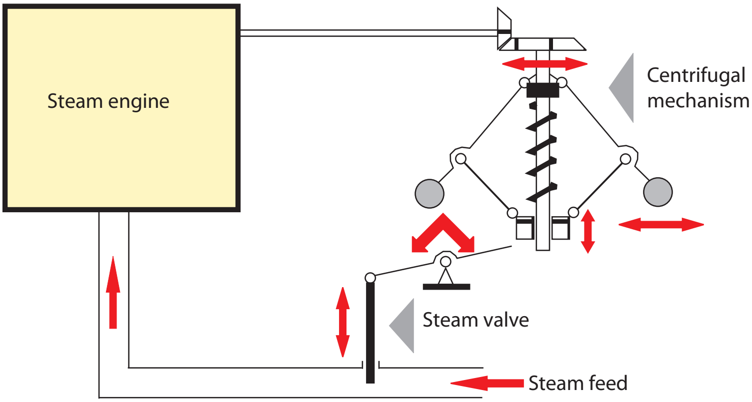


Figure 4.2. Negative feedback principle exemplified by Watt's Regulator.
The more intensely the steam engine runs, the higher the rotation speed of the centrifugal mechanism; as a result, the steam valve gradually cuts off the steam feed. In this way, the regulation of engine operation is possible.

Each scientific discipline has its specific object of study. Inasmuch as the object of environmental science is complex environmental systems, it can be defined as a science studying the systems of the Earth, their interactions and the influence of human beings on them.

The atmosphere is one of the three system components (the atmosphere, hydrosphere and lithosphere) of the Earth, and life exists in all of them. The atmosphere is composed of gaseous substances (O_2, N_2), the hydrosphere consists of water and substances dissolved in it, whereas the structure of the lithosphere, which makes up a large part of the Earth's mass, is clearly heterogeneous.

4.1.2. Atmosphere, hydrosphere and lithosphere

The total mass of the atmosphere is 5.2×10^{15} tons or approximately one millionth of the Earth's mass, and it is relatively small compared to the masses of the hydrosphere and lithosphere (Table 4.2). Intensive processes of substance and energy cycling take place in the atmosphere, and it is the most mobile compared to the other spheres of the Earth. The atmosphere plays a vital role in climate control, preventing the Earth from becoming too hot or too cold. The atmosphere diffuses the energy from the Sun, thus maintaining the temperature balance and climate life-friendly. Water vapour and carbon dioxide in the atmosphere reflects part of the heat radiating from the Earth's surface, helping to keep up temperature on the Earth considerably higher.

The composition of the atmosphere has changed with the Earth's development, and presently it is in a certain state of dynamic

Even if the atmosphere's mass is relatively small (0.00009% of the Earth's mass, 0.044% of the mass of the Earth's crust, 0.6% of the hydrosphere's mass), its role is tremendous. The atmospheric gases are involved in an active substance exchange with the lithosphere, biosphere and hydrosphere, taking active part in all kinds of migration processes of substances and elements. The existence of the atmosphere is the precondition of possibility for life on the Earth, whereas the life processes themselves substantially affect the atmosphere's composition. Human activities cause changes in all systems of the Earth, and it is the atmosphere which is affected most.

equilibrium between the geochemical processes going on in the organic nature and the activity of human beings. At the same time, the atmosphere in its present state is a result of long evolution. After the Earth had been formed, the early atmosphere was composed of methane, ammonia, water vapour and hydrogen. This atmosphere did not shield the Earth even from short-wavelength electromagnetic radiation from outer space, and it was chemically reductive. Therefore, the first living organisms evolved in water, which protected them from the electromagnetic radiation of short wavelength and precluded the breakdown of organic substances (especially DNA and proteins). The development of photosynthetic organisms brought about further changes in the atmosphere's composition. These organisms are capable of absorbing carbon dioxide and water, producing carbohydrates and oxygen. Increasing concentration of oxygen in the atmosphere created the Earth's ozone layer, and the composition of the atmosphere became very much like it is today. During the atmosphere's evolution, the concentration of hydrogen decreased as it was bound up into chemical compounds as well as diffused into outer space. Hence, photosynthesis and the development of living organisms can be deemed as the combination of factors crucial for the formation of an oxygen-rich atmosphere as we know it today.

The specific properties of the atmosphere that significantly affect the processes on the Earth are its mobility and reactivity. The atmosphere can be regarded as a barrier that protects the life processes on the Earth, as far as it absorbs charged particles and a large part of high-energy electromagnetic radiation from the Sun, which would otherwise cause damage and destruction of living organisms. Radiation with a longer wavelength and weaker energy can reach the Earth's surface, while short-wavelength radiation (ultraviolet light, X-rays, γ-rays) is absorbed in the upper layers of the atmosphere. The atmosphere has an indispensable role in balancing the Earth's temperature. The atmosphere contains carbon dioxide and oxygen. Plants use the former for photosynthesis, while living organisms use the latter for breathing. Furthermore, the atmosphere plays a vital role in the global cycling of substances (carbon, sulphur, nitrogen, metals) and in the hydrological (water) cycle. In addition, a considerable part of meteorite mass coming from outer space burns out in the atmosphere.

The atmosphere's high mobility also supports transport of airborne pollutants from one area of the Earth to other regions and even their dispersion on a global scale. To be sure, a large part of the processes taking place in the biosphere depend on the composition of the air that is used for maintaining life processes, especially in the case of much more complicated organisms. Even microscopic amounts of toxic substances can cause adverse effects on human health if exposure takes place for longer periods of time.

Temperature and the atmosphere's chemical composition can also be quite different at different heights. The atmosphere has a layered structure; therefore, depending on the distance from the Earth's surface, many of its characteristics as well as composition are variable (Figure 4.3). The upper layers of the atmosphere have a considerably different composition than the much denser lower layers, in which the main mass of the atmosphere's gases is concentrated (the air mass within 30 km from the Earth's surface makes 99% of the total mass of the atmosphere). The Earth's atmosphere is in a state of dynamic equilibrium. The atmospheric pressure changes evenly depending on the distance from the Earth and other factors. However, the temperature decreases within the troposphere, then it increases again in the stratosphere due to the interaction of atmospheric gasses with solar radiation. High-energy electromagnetic radiation from outer space initiates ionisation in the upper layers of the atmosphere, splitting even stable molecules. Gas molecules reach high speeds as a result of collisions with the quanta of electromagnetic radiation in the rarefied air of the atmosphere's upper layers. At the same time, these processes govern the sorption of electromagnetic radiation, which is most intense at the top layers of the atmosphere, although it occurs, to a large extent, at lower layers as well.

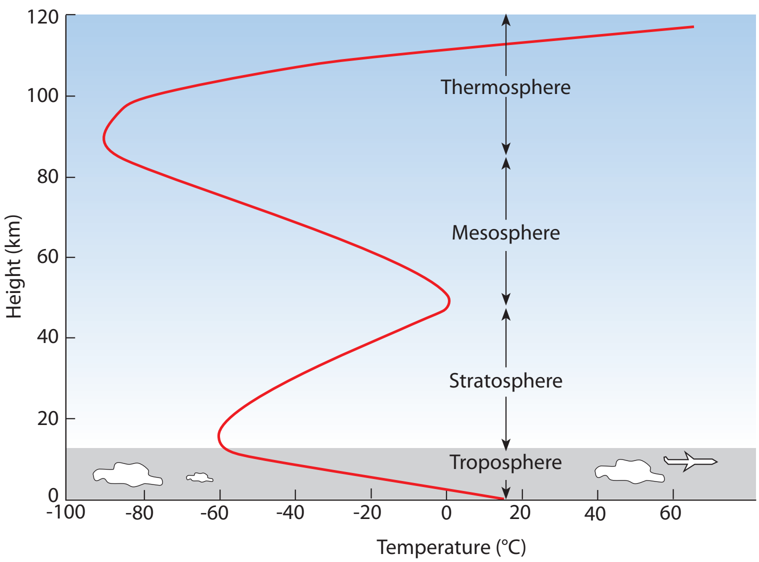


Figure 4.3. Variability of the Earth's atmosphere and temperature depending on the distance from the Earth's surface

The layer closest to the Earth's surface is called troposphere. The troposphere's height and processes taking place in it depend on the Earth's shape, movements of air masses as well as many other factors, including the anthropogenic ones. Since water vapour condensates at the upper limit of the troposphere, it does not reach the atmosphere's upper layers, where water molecules could be split in photochemical reactions, and the resultant hydrogen – diffused into outer space.

In the stratosphere, air temperature rises as the distance from the Earth increases. The rise in temperature is a consequence of photochemical reactions in the stratosphere – first of all, the formation and disintegration of ozone molecules, and also the intensive sorption of ultraviolet light.

The concentration of gases that form the upper layers of the atmosphere is considerably lower. These gases are in an ionised state, and they are subject to the influence of high-energy electromagnetic radiation coming from the Sun and outer space. Therefore, molecules move at much higher speeds in the rarefied air of the upper atmosphere. Reactions taking place in these parts of the atmosphere are rather different from those near the Earth's surface.

The hydrosphere is the whole of all water on the Earth's surface and in the Earth's crust near the surface. The World Ocean comprises the largest part of it. The cycling of substances is mostly associated with the Earth's hydrological cycle. The presence of water is a precondition for life on the Earth, and the existing forms of living organisms are to a great extent determined by water. Moreover, water is the main substance forming living organisms. Water is not only the main component of the hydrosphere; it also significantly affects the processes in the biosphere, atmosphere and – being a critical factor for many geological processes – the lithosphere. The role of water in the environment is decisive not only due to its total volume on the Earth but also due to its substantial properties.

The mass of the hydrosphere is 1.5×10^{18} tons, and its total area (ocean + glaciers and ice caps + lakes + rivers + swamps + wetlands) is 383 million square kilometres, which is 75% of the total area of the Earth's surface (510 million square kilometres).

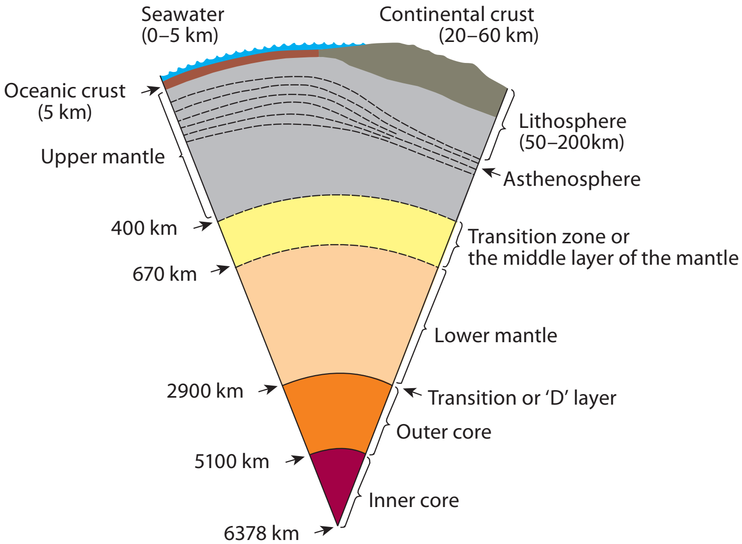


Figure 4.4. Inner structure of the Earth

The hard and rigid outer layer of the Earth – the lithosphere – is up to 200 km deep, and it comprises the Earth's crust and the outer part of the upper mantle. The lithosphere is underlain by the asthenosphere and the deeper part of the upper mantle made of magma that can come to the Earth's surface during volcanic eruptions. The Earth's outer core is liquid, and it makes up ~30% of the Earth's mass, whereas the inner core is solid and composed mostly of iron and nickel (Figure 4.4).

4.1.3. Biosphere[1]

The biosphere is the part of the Earth's environment in which living organisms are found, and it comprises the upper part of the lithosphere, the lower part of the atmosphere (troposphere) and the entire hydrosphere. The biosphere is simultaneously the entirety of all living beings (biomass) and their habitat environment. The biosphere is the space inhabited by living organisms in different concentrations. Whereas there are only a few bacteria per cubic meter in the upper layers of the atmosphere, there is not only high biological diversity but also a huge number of individuals within a specific unit area in the tropical rainforests of the equatorial zone. The biosphere is an extremely complicated and dynamic system which is affected by a multitude of different external factors, including contingent ones, such as the tectonic processes in the Earth's crust, ice covers and natural disasters.

The total number of hitherto known species of animals and plants reaches almost 3 million; from these, almost 300 000 are autotrophs, i.e. organisms producing the primary biomass. All other organisms are heterotrophs – they are the consumers of the primary biomass. Angiosperms have the largest number of species among plants, whereas insects, molluscs and vertebrates champion among animals. Fungi – being neither plants nor animals – have a special place among living organisms. They also are heterotrophs and have a vast number of species.

The total estimated global mass of living biological organisms is the biomass, and it ranges from 2.4×10^{12} tons to 1×10^{13} tons of dry matter, the largest part of which is phytomass (phytoplankton, trees, grasses), whereas the amount of zoomass is estimated from 2 to 10 per cent of the total biomass. The total of approximately 2.3×10^{11} tons of biomass is produced annually. Biomass constitutes 0.01% of the mass of the Earth's crust, and it would make a 2 cm layer if it were evenly dispersed over the Earth's surface. The largest amounts of biomass are concentrated in tropical rainforests – 65 kg/m^3 on average, whereas in boreal forests (taigas) it is 20-25 kg/m^3, in fertile zone steppes – 1 kg/m^3, in deserts – 0.25 kg/m^3. The concentration of biomass in the World Ocean at large is close to that of deserts, while in some places it is comparable to steppes and savannas. However, marine organisms have higher rates of reproduction and decomposition because their biological cycling is more intensive. Plankton is the largest and most significant community of living organisms on this planet. Although the mass of living matter is relatively small compared to the mass of the Earth's crust, the cycling processes there are much more intense. It is estimated

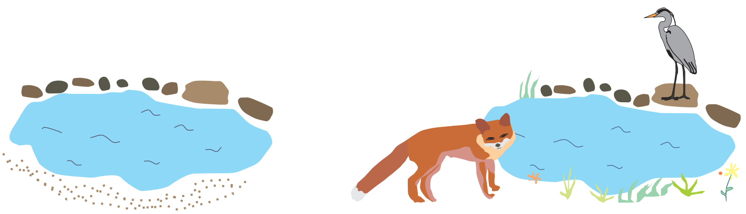
[1] This chapter has been prepared with contribution of prof. V. Melecis.

that the biomass produced by plankton during the entire period of its existence on the Earth by far exceeds the mass of the Earth's crust.

Living systems – unlike the non-living ones – actively interchange with the environment, constantly taking organic and inorganic substances and energy from it and excreting the waste products of life processes back into the environment. The main categories of living systems are cell, organism, population and species community. Cells and organisms are excitable, i.e. they actively react on environmental changes, grow, develop and reproduce. The cell is the basic structural element of organisms, the organisms of one species make a population, while the species that are interrelated or have similar demands from the environment constitute communities of species. A species community and its non-living environment inhabited, used and transformed by the species together make a system of a yet higher category – an ecosystem, in which the components of both organic and inorganic nature are combined. Each species is unique, and it has specific and distinctive functions in the ecosystem. All species of organisms living on the Earth can be classified into four kingdoms: bacteria, fungi, plants and animals (viruses are not included in this classification). Even if the number of already classified species is overwhelming, it is deemed that scientists have not yet discovered the greatest part. It is estimated that the total number of species on the planet could be at least 13 million.

The living components of an ecosystem are made up of the organisms of different species that populate the same habitat, usually interact and make a food chain. The whole of species within an ecosystem is called a species community. The whole of all components of non-living nature (rocks, water, air) that host a species community is called a biotope (Figure 4.5).

Ecosystems can be of different sizes, from micro-ecosystems, such as a rotting stump or a puddle, to meso-ecosystems and macro-ecosystems, such as a forest plot, a lake, the island of Madagascar or the Pacific Ocean. All the ecosystems of the planet constitute the mega-ecosystem – biosphere (Figure 4.6). Ecosystems are open systems, which means that they continuously receive and emit energy and different substances.



Biotope

Biotope + species community = ecosystem

Figure 4.5. An ecosystem is made up of a whole of elements of non-living nature (biotope) and a whole of living organisms (species community)

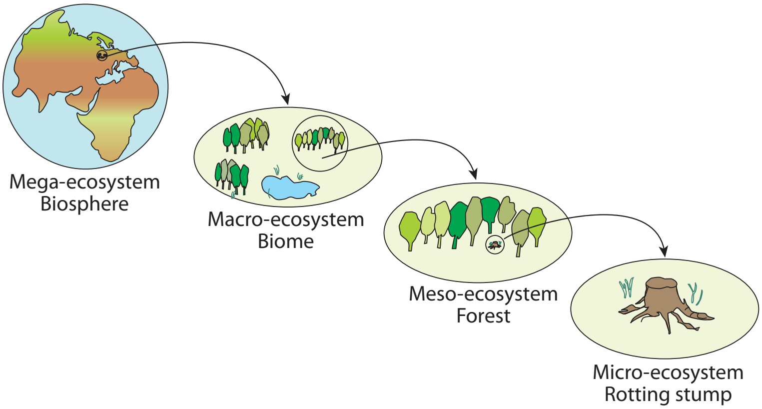


Figure 4.6. Hierarchy of ecosystems

Biosphere as the most comprehensive ecosystem is at the top of the hierarchy. Larger territories with homogeneous natural conditions can be singled out of the biosphere – they are called biomes. Meso-ecosystems, such as separate forest or grassland areas, swamps and lakes, in turn, can be singled out of the biomes.

The main function of an ecosystem is to maintain life continually, synthesising organic substances with complex molecular structure – such as cellulose, sugars, proteins and fats – from elementary inorganic substances, such as gases, water, salts. When organisms die off, they decompose back into elementary substances.

Notably, ecosystems cannot be described in spatial terms only, because there are no exact boundaries between them – unless nature itself has demarcated such boundaries, for example, the line between dry land and water. Usually the transition from one ecosystem to another is gradual, and the transition area is called an ecotone (Figure 4.7). Therefore, the boundaries drawn on the ecosystem maps are quite relative – they often do not exist in nature.

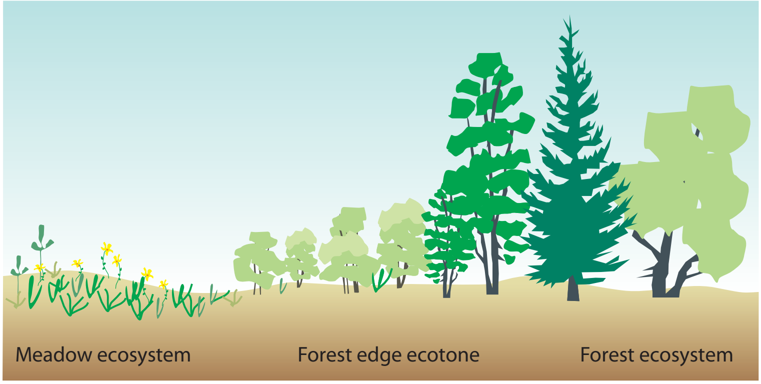


Figure 4.7. Boundary between the forest and meadow ecosystems makes a forest edge ecotone – brushwood, which contains both forest and meadow species

Within an ecosystem, there are extremely diverse bonds or interrelations between different species and elements of inorganic nature. These bonds are much closer within a single ecosystem than between different ecosystems. There is no question that the most important of these relations are food or trophic (from the Greek trophe, 'food') relations, when one species consumes another species as food. For instance, there are trophic relations between herbivore species and plant species, between predators and their prey, between parasites and their host species. However, there are other forms of relations among species apart from the trophic bonds. These relations can be, for example, mutually beneficial or symbiotic (Figure 4.8), or they can be just the opposite – competition among species for food resources or a habitat.

Figure 4.8. Lichen is a symbiotic association of alga and fungus

There also are other types of inter-species relations: when one species subsists on the food leftovers from another species, finds habitation at places inhabited or forsaken by another species or just accidentally warns another species about imminent danger.

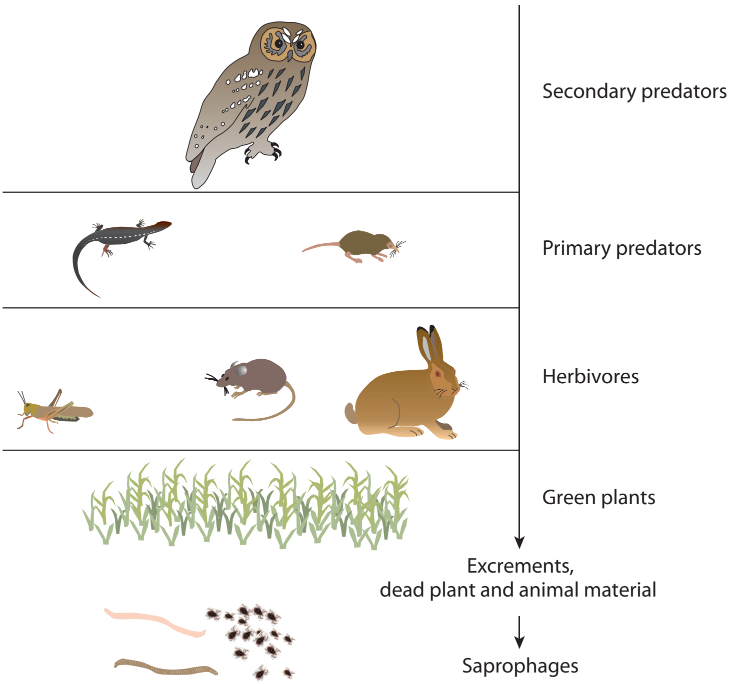


Figure 4.9. Ecological food chain

The trophic relations among species make the structural basis of ecological food chains and food webs (Figure 4.9). Energies and substances flow through ecological food chains. Green plants are the primary producers that make the first link of the food chain.

Using the energy from the Sun, they produce organic substances from mineral substances, water and carbon dioxide by means of photosynthesis. The species within the other links of the food chain are unable to use solar energy directly; they can only consume the energy that is already enclosed in the matter of green plants. The organic substances produced by plants and their accumulated energy are first of all available to plant-eating insects, birds, mammals and other animals living on plant food. Plants are basically composed of cellulose – an organic substance that is hard to digest. Herbivores are able to digest cellulose with the help of micro-organisms that inhabit their digestive tracts as symbionts. In this kind of symbiosis, the animal provides shelter for the micro-organisms in its digestive tract, while the micro-organisms help the animal digest the swallowed plant food. Since cellulose has a low energetic value as food, herbivores have to eat frequently and in large quantities in order to acquire the energy they need.

The ecological food chain represents the feeding hierarchy of organisms in an ecosystem as well as the flow of substances and energy in it. The ecological food chain ordinarily consists of three to four trophic levels. The first level comprises autotrophic organisms that make their body matter by using solar energy and the inorganic substances taken from soil or water. All green plants are autotrophic, including the algae growing in waterbodies. The green plants produce their growth substances by means of photosynthesis. For this reason, they are called producers. There also are autotrophic bacteria, though they are less widespread in ecosystems. They synthesise their cell matter by means of chemical energy. All other levels of the food chain consist of consumers. The second level comprises herbivores that consume plants to obtain energy and the needed substances. The third level comprises the primary predators and parasites that use herbivores for food. In many ecosystems, the primary predators are also endangered, for they are eaten by the secondary predators in turn. The amount of solar energy available at each subsequent level of the ecological food chain is no more than 10-15%. This is because most of this energy is used for the metabolism, growth and reproduction of organisms at each level and some energy is lost as heat. For this reason, food chains are not long. A decrease in the amount of energy in the food chain is reflected by the number and total biomass of the organisms at each level. Usually there are more plants than herbivores and more prey than predators. The ecological pyramid of numbers shows this rule graphically (Figure 4.10).

The food chain also includes decomposers. They obtain the necessary energy and substances by decomposing the remains and excrements of organisms accumulated within the entire food chain.

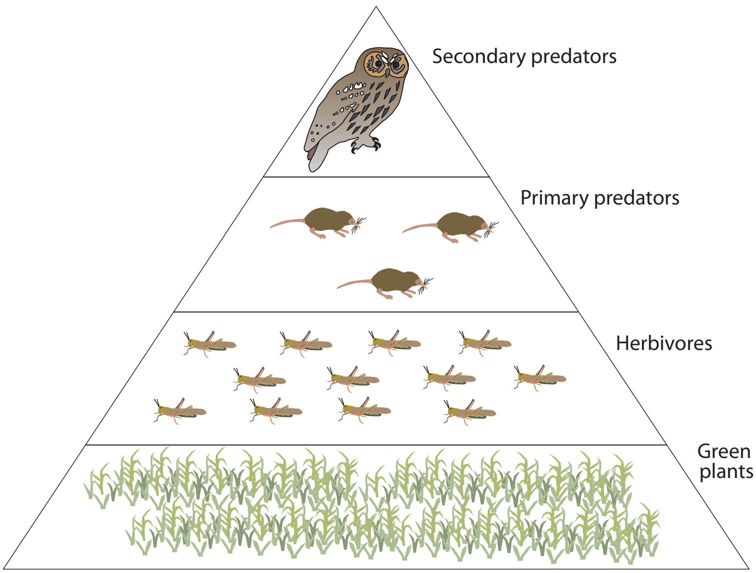


Figure 4.10. Ecological pyramid of numbers. Energy deficit and losses in the trophic food chain causes the situation when usually within an ecosystem there are more plants than herbivores and more prey than predators.

These organisms are called saprotrophs (from the Greek sapros – 'rotten', trophos – 'feeding'). It is worth noting that the ecological food chain is more of an abstract concept. In reality, many species use both plants and animals for food, for example, bears. Therefore, one and the same species can subsist at several trophic levels. Accordingly, a food web is a better way of representation of actual trophic relations among species (Figure 4.11). Each node of the food web denotes a particular species, whereas the links with other nodes indicate the trophic relations of these species with other species within the ecosystem. Thus, one can say that ecological food chains represent not so much relations among species but rather the flow of energy and substances within an ecosystem in general.

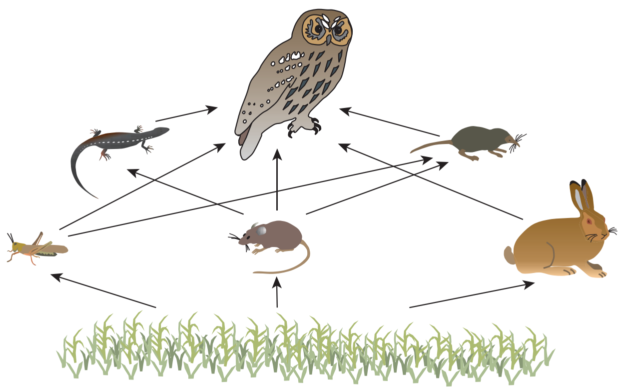


Figure 4.11. Food web. Species that act at different levels of the food chain make the nodes of the food web, whereas species that consume just one type of food are linked to the web with a single link.

Ecosystems at different levels of hierarchy are not isolated from one another; rather, they are interconnected in innumerable ways. For this reason, processes taking place in a system at a lower level affect both the neighbouring systems at the same level and all the ecosystems at higher levels in the ecosystem hierarchy. Thus, the number of migratory birds of a particular species, for example, the Black Stork, in some regions of Latvia depends on the survival success of this species in Africa.

The Amazonian rainforest deforestation causes not just local climate changes; it also affects climate in the entire region of the Amazon Basin, South America and the Pacific Ocean, because the rainforest ecosystems, by means of intensive evaporation of water and release of specific substances into the atmosphere, determine the height of rain cloud formation above the region. Ultimately, these changes affect the global climate as well. Admittedly, today's knowledge on causal relationships in ecosystems is still incomplete. Theoretically it is possible that minor changes in one element of the system might cause significant changes in the whole system. This principle is metaphorically denoted as 'the butterfly effect', and it also applies to causal relations in ecosystems, as expressed by the saying that the flap of a butterfly's wings in the rainforest of South America can set off a storm in Europe. A small increase in the concentration of phosphorus-nitrogen compounds in a lake under favourable water temperature may cause an avalanche-like multiplication of algae and cyanobacteria (blue-green algae) that has a substantial effect on the whole ecosystem of the lake.

The hierarchic structure of ecosystems spatially manifests itself as the diversity of biotopes within a single ecosystem. A large diversity of biotopes is characteristic of natural landscape ecosystems, where all kinds of ecosystems alternate: different forest types, dry and wet meadows, peat bogs and marshlands, dunes, lakes. Landscape ecosystems with a low diversity of biotopes, in turn, in many cases are human-made: large tracts of human-planted forest, agricultural fields and pastures.

Species communities or biological communities represent the living components of the ecosystem. Biological communities consist of bacteria, fungi, plants and animals. These organisms depend on environmental conditions (temperature, moisture, soil fertility), at the same time transforming these conditions themselves. For example, plants with roots and litter as well as animals with digging and excrements transform non-living rocks into soil. Earthworms play an outstanding role in this process. The famous British natural scientist Charles Darwin once compared them with a farmer's plough because there are hundreds of earthworms per square meter of a field, and they continually feed on the soil, so that almost all of the field’s topsoil passes through their digestive tracts within the period of one year. Earthworm castings are called coprolites, and they are chemically stable structural elements of the soil. In fact, they make the soil fertile by becoming the activity centres of the microbiological processes taking place in the soil.

A characteristic feature of a biological community is species diversity measured by the number of species within the community. The highest species diversity is found in the ecosystems of tropical rainforests and coral reefs. For example, the entomologist Terry Erwin has discovered that an average of 1200 species of beetles inhabit the foliage of one species of tree in the Panamanian rainforest. Of course, the species diversity is much lower in the forest ecosystems of the northern and temperate zones, where the environmental conditions are more severe. For example, in coniferous forests, the number of species can be easily counted on the fingers of one’s hand. Nevertheless, tens of different species of small arthropods and worms live in the forest soil.

Ecosystems constantly change and develop. Biological communities transform into different ones, with a different composition of species. This development process of ecosystems is called ecological succession. A telling example of ecological succession is a field overgrown with weeds and grass, transforming into a meadow; then, the meadow is overgrown with shrubs; and, finally, the shrubbery transforms into a forest (Figure 4.12).

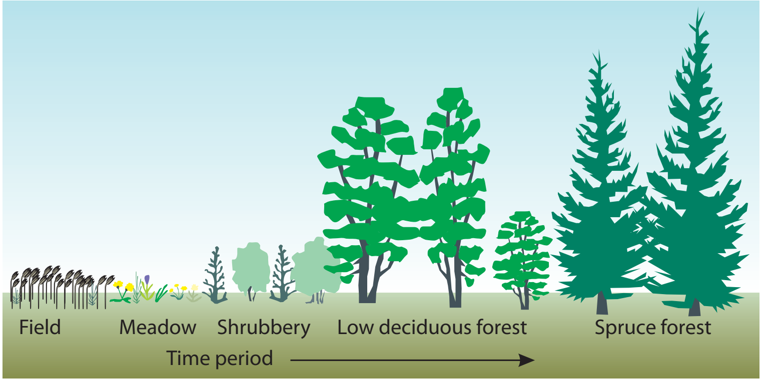


Figure 4.12. Ecological succession in terrestrial ecosystems

A field becomes overgrown and transforms into a spruce forest within a period of approximately 80-100 years. Several stages can be distinguished in this process. During each stage, there is a distinctive biological community with a specific composition of plant and animal species.

Ecological successions can be of different durations: from relatively short-term to very long. There can be short micro-successions that run for about a few weeks. In contrast, a gradual overgrowing of a lake and its transformation into a swamp may take thousands of years (Figure 4.13). The remains of aquatic plants and animals gradually settle on the lake’s bottom; consequently, it becomes shallower and shallower. Overgrowing also takes place from the lake's shores; consequently, the open water area becomes smaller and smaller – until it disappears completely.

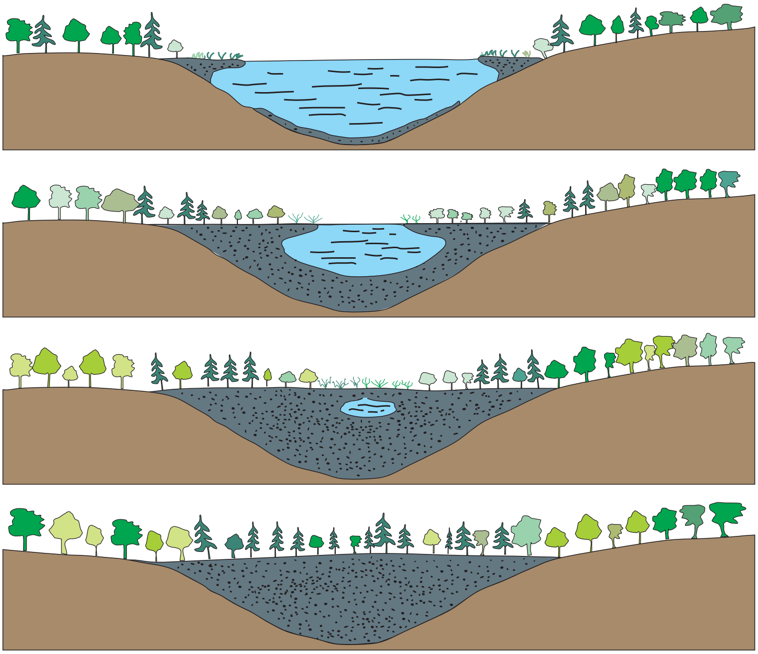


Figure 4.13. Ecological succession in an aquatic environment

The main characteristic feature of ecological succession is the changing composition of species in an ecosystem. The total biomass of living plants and animals and its productivity within the ecosystem change with that. Parallel to that, the mass and productivity of organic substances produced in the ecosystem also change. Thus, another feature of ecological succession is changing amount of biomass produced within a specific unit of time. There are two main types of succession: primary and secondary. In the case of primary succession, the development process of an ecosystem starts on bare rocks, for example, on volcanic lava, in a sand dune or gravel pit. Micro-organisms, algae, lichen and moss appear first. When these organisms die off, organic substances gradually accumulate, and the soil is formed. After that, plant and animal species start to propagate, successively replacing one another along with the development of the ecosystem.

In the case of secondary succession, an ecosystem starts to develop following the impact of some forceful external factor, for example, forest fire, hurricane, deforestation, ploughing the soil and the like. In this case, succession takes place on pre-existing soil and with more or less developed or reduced biological community. In accordance with the theory of succession, an ecosystem in the process of development works its way towards a definite final goal – an ecological climax. Once the climax is reached, the ecosystem does not develop any further.

Humans also are part and parcel of an ecosystem – one of the species of living organisms. However, humans surpass any other organisms in their ability to influence ecosystems most, to use the biological production of these ecosystems, to change the composition of species as they consider necessary. Needless to say, to manage the ecosystems successfully, a good knowledge of their functioning, the organisation of species within them are required.

The elements, substances and energy of the Earth are in the process of continuous cycling, which is described by the cycles of substances called biogeochemical cycles – because they encompass a variety of chemical conversions and geological processes, and living organisms take an active part in these cycles. The source of elements (for example, oxygen, sulphur, carbon) usually is the lithosphere. From there substances can make their way into the atmosphere and hydrosphere through volcanic eruptions and weathering of sedimentary rocks. Substances and elements also enter the atmosphere from the hydrosphere. Moreover, the processes related to water cycling in nature are crucial. Living organisms in the biosphere assimilate substances from the lithosphere, hydrosphere and atmosphere, and when they die, the substances return to the environments related with the biosphere.

With their actions, humans are capable of sustaining or destroying the ecosystems of the planet. Since the destruction of the biosphere would bring the very existence of human beings to an end, humans should be objectively concerned with sustainable development of ecosystems. When there is no sufficient knowledge on some ecosystem, we should act by observing the precautionary principle. In accordance with this principle, if there is a suspicion that certain actions could have harmful consequences, the actions in question are inadmissible. If an interference with the ecosystem does take place, it should be done step by step, carefully assessing the consequences of each step before taking the next one.

4.2. Cycling of elements and energy on the earth

The cycling of substances and elements is maintained by the flow of energy reaching the Earth from the Sun. The flows of energy govern the physical processes (for example, water evaporation and condensation and atmospheric circulation that creates wind) as well as chemical reactions occurring in the environment. The energy of the Sun makes the development of living organisms possible. Both chemical elements (for example, nitrogen, magnesium, sulphur) and substances (for example, water) are subject to biogeochemical cycling. Many elements that participate in the cycling of substances constitute the basic building blocks of living organisms. Carbon and oxygen make up to 80% of the mass of a human being. Other elements are found in trace amounts in the Earth's crust and in water; still, they are indispensable for sustaining life processes (for example, phosphorus, boron, copper).

Thus, both biological and geological processes govern the cycling of substances and elements, and, essentially, the concept of matter cycling discloses the nature of geological changes, physical processes and chemical reactions in the environment as well as transformations of biological systems (living organisms). The cycling of substances in the geological environment includes the processes that began after the Earth was formed. During the Earth's formation process, a solid crust was generated, and it was affected by periodic eruptions of the Earth's liquid inner, reaching the Earth's surface (Figure 4.14) and creating extrusive magmatic rocks. The composition of these rocks changed during the process of their erosion (disintegration), making sedimentary rocks. The latter, in turn, compacted, creating metamorphic rocks (for example, marble originated from the metamorphism of limestone).

Almost all the minerals on the Earth have originated in geological processes. The minerals that have formed in the Earth's interior or on its surface can remain almost unchanged for a very long time. If the physical and chemical conditions and composition of the environment undergo significant changes after the minerals have formed, their original properties and composition are transformed: they start weathering, new minerals and their aggregates are formed, and these new formations are more stable in the new conditions. These transformations of minerals take place constantly. There are minerals that change so slowly that these changes are not commensurable with the human lifespan or even with geological time. In contrast, there also are minerals that are unstable and can rapidly change under the influence of sunlight, air or moisture.

Figure 4.14. Layers of sedimentary rocks (Devon, the UK). Sedimentary rocks have originated from the transformation of minerals from the Earth's solid crust. They moved with water flows and were deposited in waterbodies. The different composition of layers is evidence for environmental condition changes in the atmosphere, hydrosphere and biosphere.

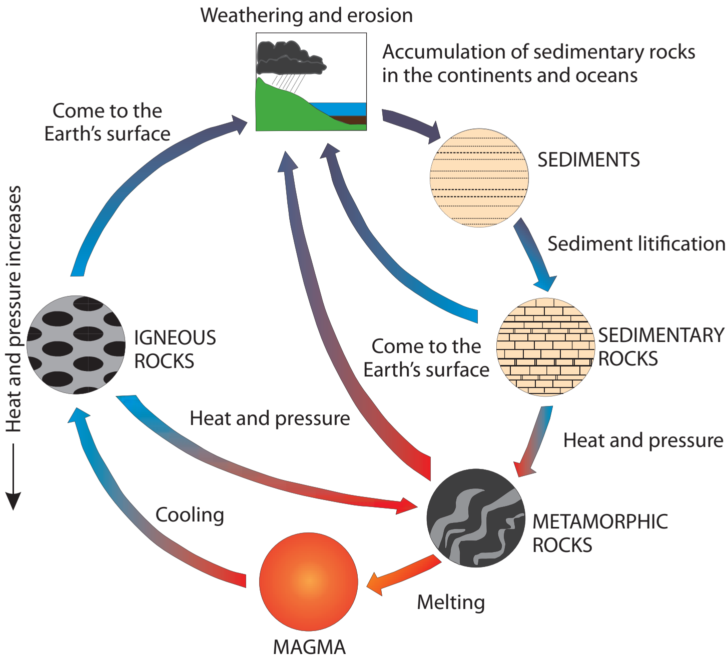


Figure 4.15. Rock cycle

Accordingly, different minerals have quite different roles in the formation of the Earth's crust. Some minerals are enduring and stable, and they have remained intact throughout the environment, pressure and temperature changes. Others, in contrast, are dynamic, have repeatedly changed their mineral form and play an active role in the transformations of the composition and properties of the Earth's crust. This process is called the rock cycle (Figure 4.15), and for stable minerals it can last for billions of years.

4.2.1. Energy flow and the Earth's climate

The main source of energy on the Earth is the Sun. The key factors that determine the extent to which the Sun's energy reaches the Earth are the following:

- distance covered by radiation;
- angle at which solar radiation reaches the Earth's surface;
- composition of the atmosphere and the interaction of solar and cosmic radiation with gases forming the Earth's atmosphere.

Earth's energy balance

Different types of radiation reach the Earth: the Sun's electromagnetic radiation and the flow of ionised particles (for example, oxygen or helium atomic nuclei) and elementary particles, as well as the flow of particles and radiation from outer space (cosmic radiation). The Earth's climate is mostly affected by the flow of electromagnetic radiation. The radiation from the Sun that reaches the Earth comprises the full spectrum of electromagnetic radiation: γ-rays, X-rays, ultraviolet radiation as well as the visible light, infrared radiation and radio waves. The energy of electromagnetic radiation decreases with the increase in wavelength; therefore, most of the radiation that reaches the Earth has high energy and a relatively short wavelength.

A considerable part of solar radiation (γ-rays, X-rays and ultraviolet radiation with short wavelength) does not even reach the Earth's surface because it is absorbed already in the upper layers of the atmosphere or is reflected back into outer space. High energy solar radiation transformations in the Earth's atmosphere are determined by the interaction of γ-rays, X-rays and short-wavelength ultraviolet radiation with atmospheric gases.

The visible light (wavelength approx. 0.40-0.70 μm) is essential for sustaining the life of green plants and most animals, as it carries the energy necessary for photosynthesis and regulates the animal reproduction times, migration and many other life processes. Infrared radiation (thermal radiation) has a much lower energy;

nonetheless, it has a vital role in the Earth's climate formation, because it warms the lower layers of the atmosphere and the Earth's surface.

The intensity of incoming solar radiation is approximately in equilibrium with the intensity of energy reflected from the Earth's surface (Figure 4.16). The flow of energy that reaches the upper layers of the Earth's atmosphere has an intensity of ~1370 W/m². Most of this energy is reflected back into space or absorbed as a result of interaction with gases in the Earth's atmosphere. The intensity of the flow of energy that finally reaches the upper layer of the troposphere is just 342 W/m².

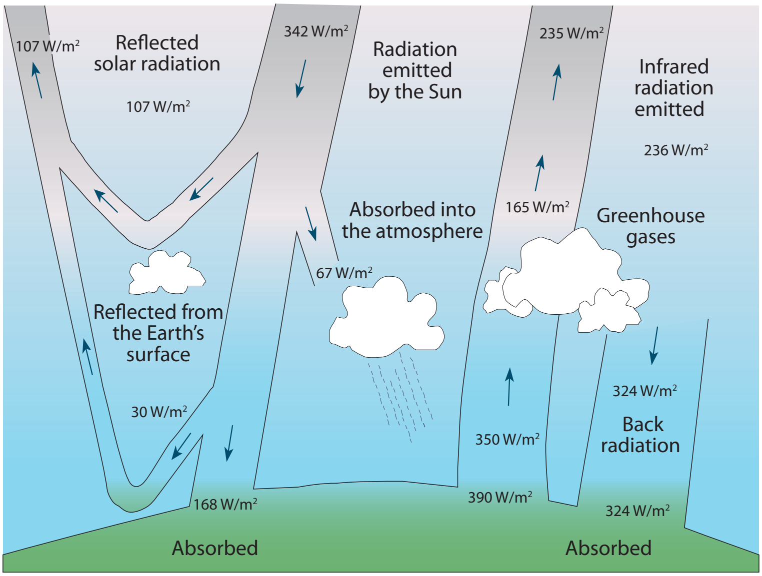


Figure 4.16. Earth's energy balance

Approximately 30% of solar radiation is reflected back into space. Part of this energy is reflected by cloud cover and small particles in the atmosphere. 51% of radiation from the Sun is absorbed by the Earth's surface, and this energy is spent for evaporation – as infrared radiation from the Earth and in convection and advection processes.

The theory that the composition of the Earth's atmosphere can affect the intensity of energy received from the Sun and the Earth's climate has been around for more than 100 years. Solar radiation warms the Earth's surface, and then the Earth reradiates this heat into the atmosphere. Since the temperature of the Earth's surface is by far lower than that of the Sun's surface, the intensity of energy emitted by the Earth also is much lower and the wavelength of this energy – much higher than that of solar radiation. The Earth's surface mostly emits infrared radiation that can interact with atmospheric gases.

Several of these gases can intensively absorb infrared radiation. These gases are carbon dioxide (CO_2), methane (CH_4), ozone (O_3) and water vapour, as well as nitrogen(I) oxide (N_2O) and the gases that are released into the atmosphere due to human activity – chlorofluorocarbons (freons).

Carbon dioxide, methane and also water vapour in the atmosphere work like greenhouse glass (Figure 4.17). They let solar radiation through, but hold up the infrared radiation reradiated from the Earth's surface. Due to this effect, these gases are called greenhouse gases. The higher their concentration in the atmosphere, the more infrared radiation is retained in the Earth's atmosphere and, as a consequence, the higher the temperature of the Earth's surface. If the Earth's atmosphere were composed of nitrogen and oxygen only, i.e. the gases that do not contribute to the greenhouse effect, the Earth's average yearly temperature would be only +6 °C (now it is approx. +15 °C).

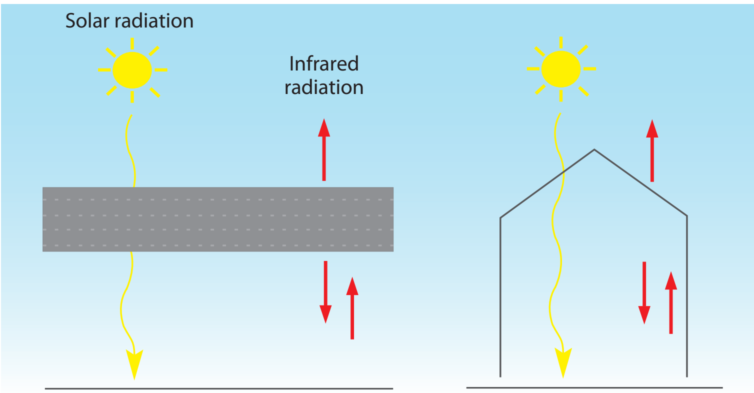


Figure 4.17. Principle of solar electromagnetic radiation absorption in the Earth's atmosphere and in a greenhouse

The Swedish chemist Svante Arrhenius proposed the hypothesis regarding the role of greenhouse gases – CO_2 in particular – in the Earth's climate formation as early as 1896. His calculation that doubling the CO_2 concentration in the atmosphere would cause a rise of the Earth's average temperature by 5-6 °C has been fully confirmed today.

Even the slightest changes in the concentrations of greenhouse gases in the atmosphere cause temperature changes on the Earth, causing further changes in the size of glaciers and ice shelves and caps, in the ocean level, patterns of currents, spatial structures of habitats and climate.

Impact of greenhouse gases on the earth's climate[1]

Each of the greenhouse gases (Table 4.3) has a different capacity to capture solar radiation and reradiate it back to the Earth. The intensity of radiation is measured in watts per square metre (W/m^2), and the measurement shows the extent to which each of these gases affects the amount of energy that reaches the Earth's surface – thus also the extent to which it affects the climate. If the radiation intensity value is positive, the gas in question facilitates the rise in the Earth's temperature; if this value is negative – it facilitates the decrease in temperature. The natural greenhouse effect maintains the temperature which is just right for creating prime conditions for life on the Earth. Moreover, the greenhouse effect in not unique on the Earth. Astronomers think that other planets show the signs of the greenhouse effect as well. For instance, it is deemed that the temperature on Venus reaches as high as +450 °C largely owing to the greenhouse effect.

Table 4.3. Variability of the greenhouse gas concentrations in the atmosphere and its effect on the Earth's energy balance

Greenhouse gas	*Gas concentration in the atmosphere, parts per trillion*		*Emission per year*	*Lifetime in the atmosphere, years*
	1998	*1750*		
Carbon dioxide CO_2*	365	278	26.4 GT[1]	
Methane CH_4**	1745	700	600 Tg	8.4
Nitrogen(I) oxide N_2O**	314	270	16.4 Tg N	120
Perfluorethane C_2F_6	3	0	~2 Gg	10 000
Freon 11 $CFCl_3$	268	0		45
Freon 23 CHF_3	14	0	~7 Gg	260

* Concentration expressed in parts per million.
** Concentration expressed in parts per billion.

A characteristic feature of many greenhouse gases is their high stability with respect to the duration until they are chemically bound or emitted from the atmosphere (Table 4.3). Water vapour is removed from the atmosphere relatively quickly in the form of

[1] Hereinafter the concentration of greenhouse gases is expressed in number of parts by volume (part-per notation) – correspondingly: ppm – parts per million; ppb – parts per billion; ppt – parts per trillion. This concentration notation shows the amount of substance per air volume. For example, 300 ppm means that a million of gas molecules in the air contains 300 molecules of the respective greenhouse gas or that a million air volume units (for example, cubic centimetres) contains 300 cm^3 of the respective gas.

Peta (P) – 10^{15}	Tera (T) – 10^{12}	Giga (G) – 10^{9}
Milli (m) – 10^{-3}	Micro (μ) – 10^{-6}	Nano (n) – 10^{-9}

atmospheric precipitation. Methane oxidises photochemically into carbon dioxide and water. Carbon dioxide dissolves in water. Nitrogen(I) oxide (N_2O) is particularly stable. Many substances released into the atmosphere due to human activity – for example, freons – are exceptionally stable, and they will influence the atmospheric processes for a very long time.

Different greenhouse gases can differently affect the Earth's climate in view of both their capacity to reflect infrared radiation and their concentration in the atmosphere. If we express the potential effect of CO_2 on the Earth's climate by 1 unit of measure, the relative potential of other substances that cause greenhouse effect to influence the Earth's temperature balance is significantly higher: for methane (CH_4) it would be 11, for nitrogen(I) oxide (N_2O) – 270 and for freon 11 (CF_3Cl) – 3 400. Knowing the amounts of radiation emitted by greenhouse gases, it is possible to forecast what kind of changes the increase in their concentrations in the atmosphere will bring about and what their overall influence will be (Figure 4.18, Table 4.3).

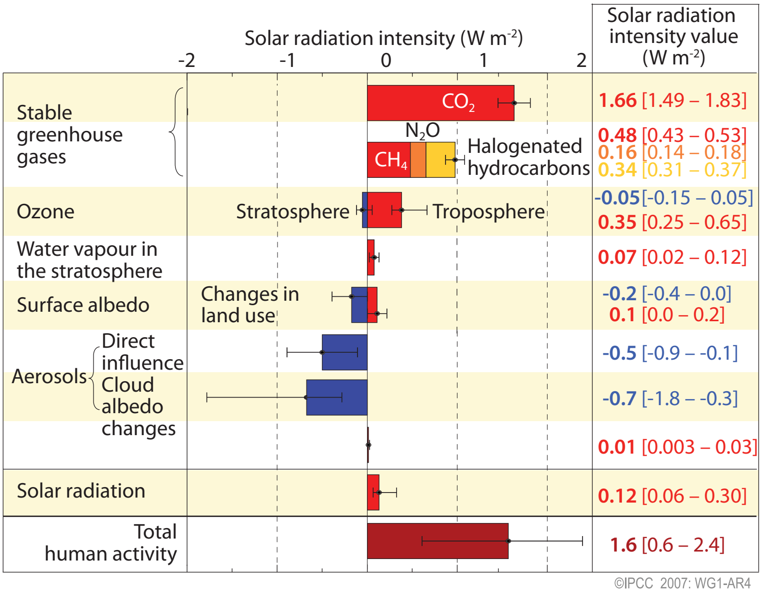


Figure 4.18. Mean global radiation intensity for the main factors affecting the Earth's climate system. The value of solar radiation intensity (radiation amount) indicates changes in reflected energy that would occur at the upper limit of the troposphere if the respective component were completely eliminated from the atmosphere.

Within the last 10 000 years, especially in the last century, the concentration of the three major greenhouse gases has significantly increased in the Earth's atmosphere. Consequently, the intensity of solar radiation reflected back to the Earth's surface has also increased (Figure 4.19).

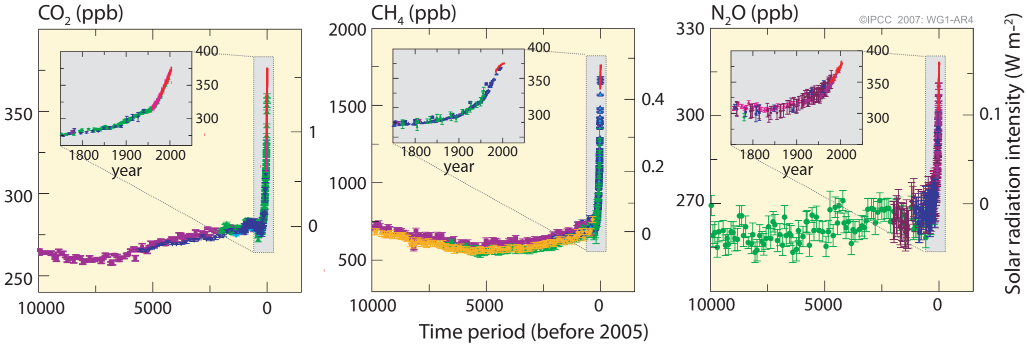


Figure 4.19. Changes in greenhouse gas concentrations and the effect of these changes on the intensity of incoming solar radiation for the period of the last 10 000 years

The biosphere (of both water and dry land) affects the composition of the atmosphere, assimilating carbon dioxide on the one hand and releasing oxygen and water vapour on the other hand. The biosphere plays a major role in the carbon cycle. Although the components of the climate system have different chemical compositions and physical properties and their effect on the Earth's climate formation is different, there is a constant exchange of matter and energy going on among them. Any changes in any climate system component – irrespective of whether they are caused by natural or by human activity – can affect the other components of the system and result in climate change. Climate change can occur as a result of both natural processes and human activity. The latter first of all affects the composition of the atmosphere as well as the ways of land use.

4.2.2. Carbon cycle

Carbon is the most important element for living organisms. With an average concentration of 350 mg/kg, carbon is not so pervading on the Earth; yet, it has an exceptional role in the cycling of elements. In the carbon cycle (biogeochemical cycle), one carbon compound is converted into others, and this process occurs in the atmosphere, hydrosphere, lithosphere and biosphere. In the lithosphere, carbon is stored in carbonate sedimentary rocks (limestone – $CaCO_3$, dolomite – $CaMg(CO_3)_2$ and others), and it also forms fossil fuel sediments (coal, oil, bituminous shale). Furthermore, large amounts of carbon compounds (carbon dioxide and methane) are stored in the permafrost zone, and they also form waterbody sediments and the decomposition products of organic substances in the soil.

In the hydrosphere, carbon compounds are present in living organic matter, carbonate ions and hydrogen carbonate ions in the form of dissolved carbon dioxide and methane. The atmosphere contains approximately 760 billion tons of carbon in the form of such compounds as carbon (II) oxide (CO), carbon (IV) oxide (CO_2) and methane (CH_4). Carbon compounds have different cycling periods at each stage of the cycle: in the atmosphere it is quite short – 3 years, in the soil – 25 years, in the oceans – 350 years, while the cycling period of carbonate rocks is more than hundreds of millions of years.

The living, photosynthetic organisms of the biosphere that continuously absorb CO_2 from the atmosphere, forming organic compounds, have vital functions in the carbon cycle. CO_2 goes through a complete cycle in the atmosphere in a relatively short period of time – approximately four and a half years.

Not all dead organisms and plants decompose immediately. A small fraction of them reach the deep parts of inland waterbodies, seas and oceans and form sediments there. The organic material that decomposes slowly becomes part of the sedimentary rock formation process and can return into the atmosphere in a natural way (for example, in the process of erosion).

Carbon dioxide from the atmosphere can enter waterbodies and dissolve there. In water, algae absorb carbon dioxide in much the same way as terrestrial plants do. In addition, some aquatic life forms extract calcium and carbon dioxide from water to build calcium carbonate shells. When these organisms die off, their shells are deposited on the bottom of waterbodies, forming limestone. In this way, part of carbon becomes involved in the sedimentary rock cycle, which will possibly bring it as limestone up to the Earth's surface again in the future. After that, the erosion process and weathering will decompose this limestone, and dissolved it will return into the ocean, and then, from the ocean, carbon will be released back into the atmosphere.

The increase in carbon dioxide and methane emissions can become a factor that will adversely affect the environmental processes and carbon cycle. Estimates show that the amount of anthropogenic emissions of CO_2 have been increasing on average for 2.5% per year within the last hundred years (Figure 4.19). Shrinking of forest areas also affects the concentration of CO_2 in the air. The current amount of CO_2 anthropogenic emissions is 9.0×0.5 GtC per year; however, depending on the World's population growth scenario, it is estimated that these emissions can increase up to 35.8 GtC per year by 2100.

Human economic activity changes the carbon cycle and enhances the release of the carbon compounds accumulated in the lithosphere into the atmosphere. Fossil fuel combustion and deforestation make CO_2 pass from the lithosphere and biosphere into the atmosphere much faster than it would occur in a natural way. At the same time, the return of CO_2 from the atmosphere in a natural way takes place much slower than when it is aided by human economic activity. In effect, the amount of CO_2 in the atmosphere irreversibly increases.

Methane plays a substantial role in the carbon cycle. Methane absorbs infrared radiation more effectively than CO_2; therefore, its increase boosts the greenhouse effect, even if methane's concentration in the atmosphere is lower than that of CO_2. Since the 60s of the last century, when the atmospheric methane concentration measurements began, its total concentration has increased for an average of 1% per year. Part of methane is generated as a result of rice and livestock farming, especially from cattle. Historically methane concentration changes, like those of CO_2, have been related to the climate changes during the ice ages and interglacial periods. However, in recent years research shows that geological processes can also be a significant source of methane. For example, such natural phenomenon as mud volcanoes is deemed to originate almost 10% of the atmospheric methane.

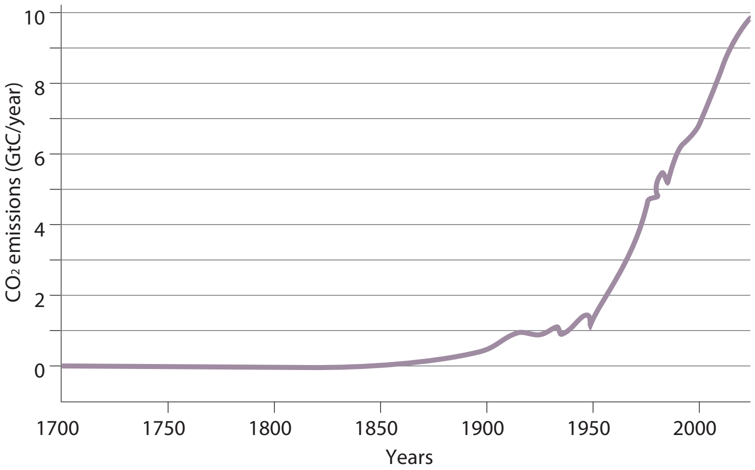


Figure 4.20. Changes in carbon dioxide emission amounts over the last centuries

The concentration of carbon dioxide in the atmosphere has increased from 280 parts per million in the pre-industrial period to 385 parts per million in 2008 (Figure 4.20). Probing the composition of the air trapped in the continental glaciers has proved that the concentration of CO_2 today is significantly higher than it had been during the last 650 000 years (180-300 ppm). Human activity is the main factor contributing to the increase of CO_2 concentration in the atmosphere and affecting the whole carbon cycle.

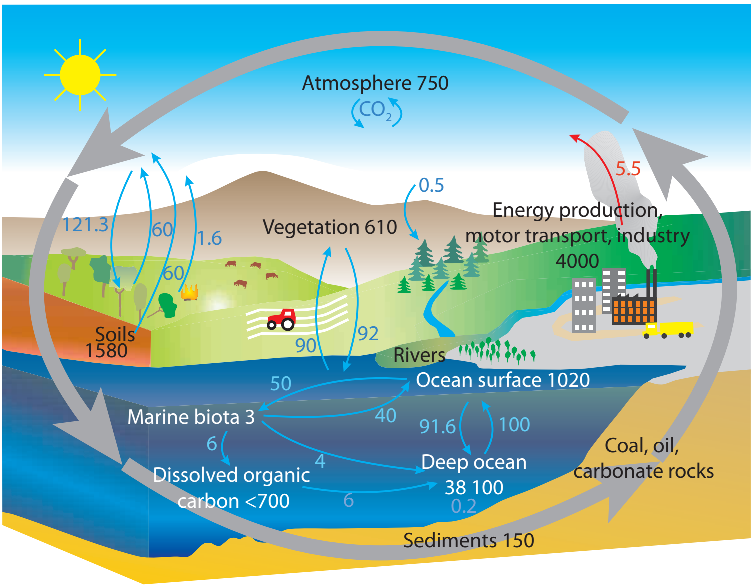


Figure 4.21. Carbon cycle.
Amounts stated in PgC, flows – in PgC/y.

4.2.3. Nitrogen biogeochemical cycle

Nitrogen makes 76% of the atmosphere's mass, and it is one of the most important chemical elements in proteins and DNA; therefore, it is one of the elements necessary for the existence of living organisms. At the same time, the concentration of nitrogen compounds in the lithosphere and hydrosphere is quite low. Unlike oxygen, nitrogen is inert, and most living organisms cannot utilise it directly, because the bonds between atoms in nitrogen molecules are very stable. Processes in the nitrogen cycle ensure the bonding of atmospheric nitrogen (N_2) into such compounds that can be utilised by living organisms.

In the environment, nitrogen compounds are found as nitrogen(I) oxide (N_2O), nitrogen(II) oxide (NO), nitrogen(IV) oxide (NO_2), nitric acid (HNO_3), ammonia (NH_3) and ammonia salts. Other nitrogen compounds either form intermediate products in various reactions, or are unstable and decompose fast. Nitrogen compounds are interrelated, and they can be converted into one another (Figure 4.22). Reactions caused by micro-organisms play an important part in the nitrogen cycle, for these micro-organisms in the hydrosphere and lithosphere are involved in the conversion of most nitrogen compounds. In other words, they catalyse the synthesis of nitrogen compounds necessary for the existence of the biosphere's living organisms. It should be noted that only a small part of nitrogen compounds become involved in the nitrogen cycle, because nitrogen

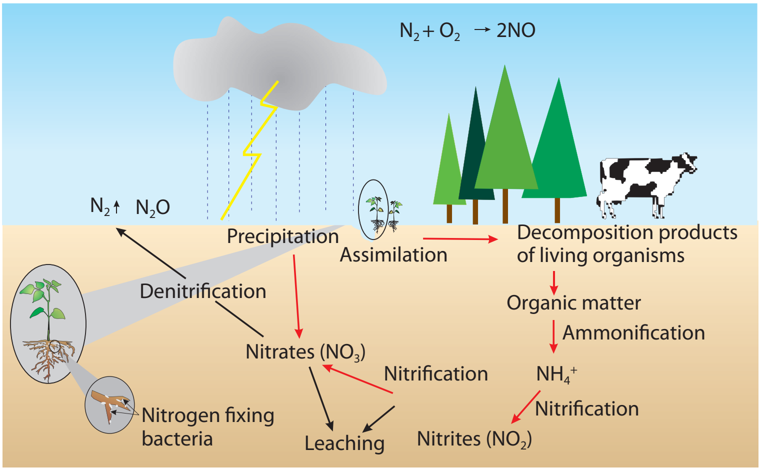


Figure 4.22. Natural processes of nitrogen compounds in the environment

reacts with oxygen in the atmosphere, but these reactions require high energy that is generated only during the lightning discharges or is found at the top layers of the atmosphere.

Chemical reactions in the atmosphere and the activity of living organisms ensure nitrogen fixation (its conversion into chemically reactive and biologically available compounds).

The main process in the nitrogen cycle is its fixation (assimilation) – the reactions through which micro-organisms fix the atmospheric nitrogen, converting it into ammonium. Bacteria and blue-green algae are able to fix nitrogen. Micro-organisms produce 1-5 kg N/ha, nitrogen fixing bacteria – 100-300 kg N/ha.

In the process of assimilation, nitrogen organic compounds are produced. They decompose and, in turn, produce ammonia or ammonium salts (ammonification). The latter are further converted into nitrates and nitrites (nitrification). Nitrification can also be considered to be the oxidation of organic and inorganic nitrogen compounds.

The final stage of the nitrogen cycle is its return to the atmosphere by means of the production of N_2 (denitrification). This process takes place in the soil. N_2O can also be produced in the process of denitrification.

Nitrogen(I) oxide (N_2O) is naturally found in the atmosphere as a product of various biological and photochemical transformations. The anthropogenic emission amounts of N_2O are small; therefore, nitrogen(I) oxide pollution – also taking into account its low toxicity – is not hazardous to living organisms. This substance does not have any odour or taste and is chemically inert. N_2O enters into the atmosphere mostly by means of denitrification processes, when the nitrogen compounds used in agriculture leach into the soil and waters, where they are reduced back into inert nitrogen gas. The amount of N_2O emissions is 100 million tons per year, and its overall amount in the atmosphere is 2000 million tons. The nitrogen cycle completes in 120 years, but the concentration of N_2O in the atmosphere has been increasing by 0.3% annually within the last hundred of years. Hence N_2O is considered one of the main greenhouse gases.

As with other key chemical elements, nitrogen cycling is graphically represented by its biogeochemical cycle (Figure 4.23).

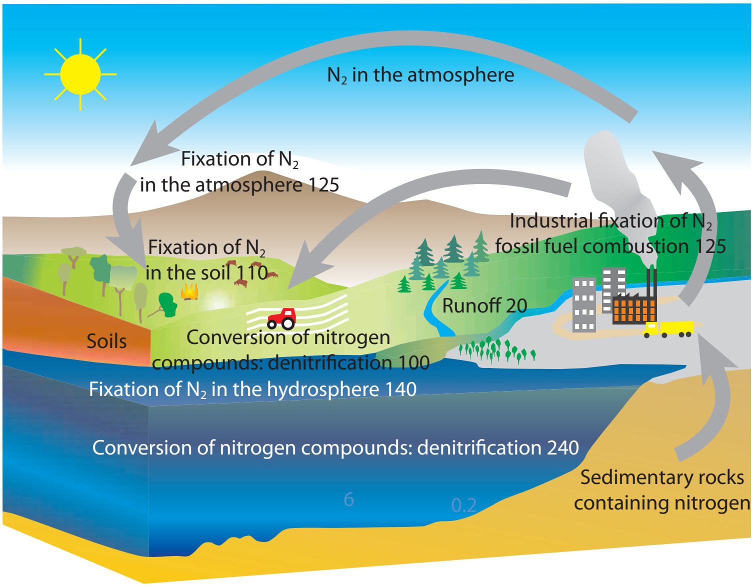


Figure 4.23. Nitrogen biogeochemical cycle Flows stated in PgC/year.

In 1914, German chemists Fritz Haber and Carl Bosch developed an industrial method for the manufacture of ammonia from atmospheric nitrogen, commencing the development of a large-scale industrial production of agricultural inorganic fertilisers. Today the total amount of approximately 100 million tons of nitrogen fertiliser is produced every year, which roughly corresponds to the amount of nitrogen fixed by micro-organisms (100-200 million tons per year) (Figure 4.24). Thus, the amount of nitrogen produced by human activity is already comparable to the amount nitrogen fixed in the natural processes of the nitrogen biogeochemical cycle, and it is estimated that the former will exceed the latter in the near future.

Considering the large production amounts of nitrogen compounds, they can adversely affect not only environmental processes but also human and animal health.

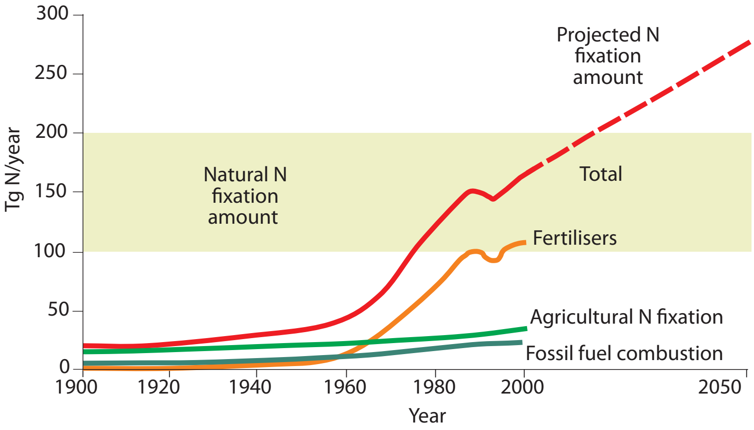


Figure 4.24. Nitrogen fixation amounts in nature and by human activity on a global scale

Nitrogen compounds are among the basic nutrients needed for plant growth, and they are used in agriculture for soil fertilisation in order to promote the growth and yield capacity of cultivable plants. Unfortunately, a significant part of the nitrogen compounds used for fertilisation leaches into surface waters and groundwaters and, along with surface runoff – further into the seas and oceans. Nitrogen compounds also fall out with atmospheric precipitation (Figure 4.25). In effect, both water and soil become oversaturated, causing eutrophication.

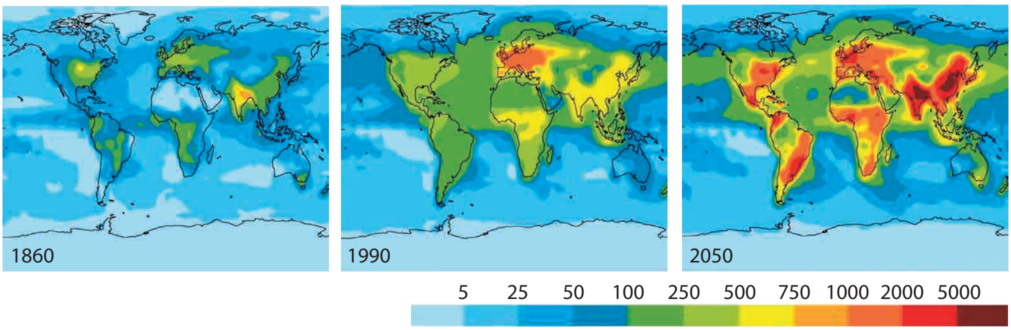


Figure 4.25. Nitrogen compound fallout (mg N /m^2/year) with atmospheric precipitation – changes in the amounts during the last centuries and a forecast

In present-day Europe, the emission of nitrogen compounds has become one of the most hazardous environmental pollution factors. It is an urgent problem for the Baltic Sea Region countries, where the concentration of nitrogen compounds initiates many harmful processes, including the pollution in the Baltic Sea. Thus, the issues related to the flow of nitrogen compounds, their utilisation amounts and emission reduction become burning issues on the agenda.

4.2.4. Phosphorus biogeochemical cycle

The environmental processes and the quality of the environment depend not only on macro-elements but also on substances that occur only in very small amounts in nature. Examples of such substances include phosphorus, many metals and their compounds and other elements, such as iodine, bromine, arsenic, selenium and others. Phosphorus is particularly important for sustaining life processes in living organisms, as it is a component in the genetic information carrier molecules – deoxyribonucleic acid (DNA) and ribonucleic acid (RNA), in many proteins as well as in the molecules responsible for cellular energy transport – adenosine triphosphate (ATP) and adenosine diphosphate (ADP). The phosphorus cycle (Figure 4.26) has a pivotal significance because phosphorus is often a limiting factor for the development of living organisms, i.e. the amount of phosphorus available for the development of organisms determines the intensity of their growth.

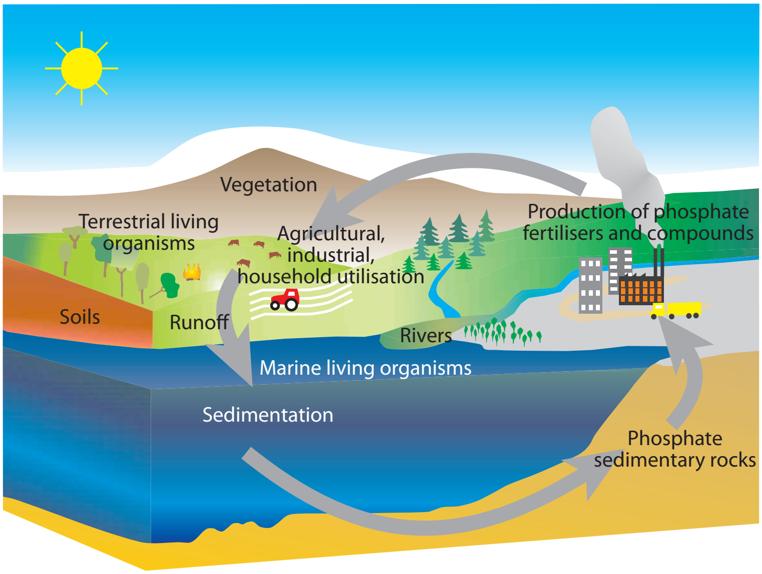


Figure 4.26. Phosphorus biogeochemical cycle

The phosphorus cycle differs from the cycles of other elements (carbon, nitrogen, sulphur and others) because it does not contain substances in gas phase as most phosphate compounds are non-volatile or solid. The amount of phosphorus compounds in the atmosphere is small, and they are usually extracted from the lithosphere's sedimentary rocks in the form of various apatites (mostly in the form of calcium phosphates) that have formed in shallow seas tens of millions years ago. When herbivores consume plants, phosphates enter the bodies of these animals. With their excrements or decay after death phosphates are returned to the soil and waters. Part of phosphorus compounds are bound as stable chemical compounds in the soil and marine sediments, forming phosphate sedimentary rocks. The natural cycling of phosphorus compounds is not intense; therefore, sedimentary rocks that contain phosphorus are concentrated in just a few regions of the world, and their weathering takes place slowly.

Phosphorus compounds are predominantly (~90%) used as inorganic fertilisers in agriculture. The estimated global utilisation of fertilisers is 15 million tons per year. The second major area of phosphorus compound utilisation is in detergents. Phosphorus compounds are added to detergents as water-softeners. Just like after the decomposition of living organic matter, virtually all areas of use of phosphorus compounds end up with their runoff into the hydrosphere after utilisation, intensifying the processes of eutrophication in waterbodies. In any case, human activity has cardinally changed the nature of phosphorus flow in its biogeochemical cycle.

References

Begon M., Townsend C., Harper J. L. (2005) Ecology. From Individuals to Ecosystems. Boston: Blackwell Pub.

Berner E. K., Berner R. A. (1996) Global Environment. Water, Air and Geochemical Cycles. N.Y.: Prentice Hall.

Botkin D., Keller E. (2000) Environmental Science: Earth as a Living Planet. N.Y.: Wiley and Sons.

Enger E. D., Smith B. F. (2006) Environmental Science: A Study of Interrelationships (10th ed.). Boston: McGraw Hill.

Geochemical Cycles. (1991) Chapter 23 in Inorganic Geochemistry (ed. Faure G.). N.Y.: Macmillan Pub.

Lovelock J. (2007) The Revenge of Gaia. London: Penguin Books.

Nebel B. J. (1990) Environmental Science: The Way the World Works. N.Y.: Prentice Hall.

Rydén L. (ed.) (2003) Environmental Science. Uppsala: Baltic University Press.

Biogeochemical Cycles. Accessible: *www.enviroliteracy.org/subcategory.php/198.html.*

Environmental Microbiology. Accessible: *www-micro.msb.le.ac.uk/109/Environmental.html.*

Leopold Education Project. Accessible: *www.lep.org/.*

World Resources Institute. Accessible: *http://materials.wri.org/topic_data_trends.cfm.*

5. GLOBAL ENVIRONMENTAL PROBLEMS

5.1. Environmental pollution and environment quality degradation

Life on the Earth is fragile, and every living being can continue to live only in the environmental conditions optimal for its life. Such factors as the rise or fall of temperature above or below the optimum, intensive flow of electromagnetic radiation (ionising radiation) or the action of chemical substances can annihilate living organisms and – in a wider context – life itself. Living organisms can also perish due to depletion of needed nutrients. Likewise, the impact of natural hazards and calamities can create unfavourable conditions for living organisms. Many times during the existence of the Earth, the number of species was reduced even by more than half as a result of various disasters. Moreover, living beings themselves can cause their living environment changes that have no less dramatic consequences.

The past, present and potential global threat of environmental pollution and degradation can to a great extent be considered one of the main factors that has an effect on the formation of society's environmental consciousness.

Environmental pollution is quite often associated with chemical pollution, and we will deal with that in a bit more detailed manner below. Pollution of the environment by chemical substances can be classified depending on the properties and structure of these substances. Environmental contamination with metals or their compounds (Cu, Pb, Co, Hg and others) and toxic trace elements (F, B, As, Se and others) can be marked out first. Organic pollutants, such as pesticides, can have a negative impact on the natural environment. Organic substances can be formed as a result of the decomposition of household products, pest control with pesticides and herbicides as well as industrial pollution. The environmental pollution threat increases if the organic substances that have been released into the environment are persistent (Persistent Organic Pollutants – POP), i.e., if they remain there for a long period of time (even several decades in the soil). Such substances as pesticide DDT, dioxins, polychlorinated

Pollutant is any substance released into the environment as a result of human activity or natural processes that has an adverse impact on living organisms. Environmental degradation means that the environment becomes unusable for its designed purposes or that the development of living organisms and their communities in the environment is impeded. Environmental pollution and degradation can be caused by chemical substances, physical factors or the development of undesirable living organisms (biological factors). Different substances or factors have different effects. Any chemical, biological or physical factor is called toxic if it causes an adverse biological reaction. All toxic substances are hazardous, but not all hazardous substances are toxic. Toxic substances can be either naturally occurring, or they can be human-made (xenobiotic) – produced by means of synthesis or as by-products in the process of production of other substances.

All kinds of chemical compounds are increasingly released into the environment (Figure 5.1). To date, there are approximately 10 million known chemical substances, and a large part of them do not exist in the natural environment. There are approximately 120 000 industrially produced chemical compounds that are widely used and 10 000 substances produced in the amounts exceeding 500 kg per year. Moreover, the number of types of industrially produced substances is increasing from approximately one to three thousand new ones every year.

biphenyls and others belong to POPs. More or less chemically inert compounds in a state of fine particles can also contaminate the environment. Particles may form dust and aerosols in the air and suspensions in water.

Factors that cause environmental degradation can be classified depending on their nature. The quality of the environment can deteriorate due to physical factors, for example electromagnetic radiation, the influence of which can be quite different depending on the wavelength. Short-wavelength electromagnetic radiation (γ-rays) actively affects living organisms, and its sources are radioactive elements or reactions in atomic nuclei. UV radiation, which has longer wavelength, may have a significant effect, for example, on the human skin or growth of plankton in surface waters. Noise pollution, i.e. high intensity noise in the living or working environment, can be classified among physical environmental pollution factors. Increased amounts of heat (flow of energy) released into the environment may have quite a many-sided negative impact (thermal pollution). For example, the discharge of industrial cooling waters or warm water from thermal power plants into the environment has adverse consequences, affecting the growth of aquatic organisms. Last but not least, living organisms can also cause serious environmental pollution. They can be infectious agents, parasites as well as the living organisms whose metabolism or decay products are harmful to humans or other living organisms.

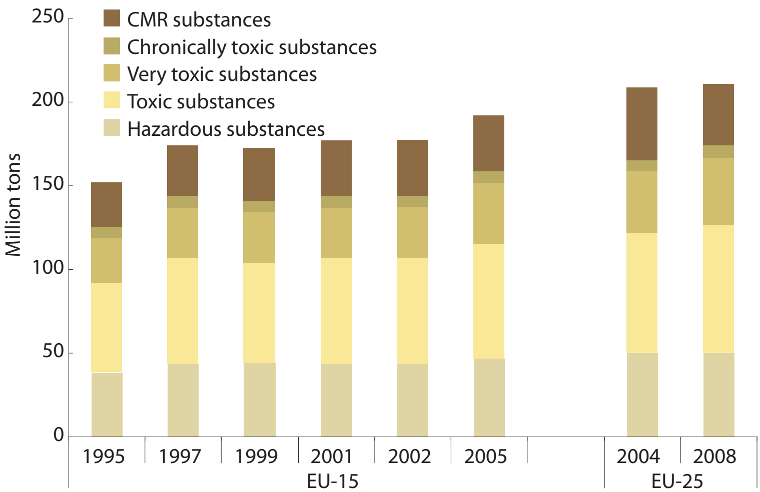


Figure 5.1. Production amounts of hazardous chemicals in the European Union Member States. CMR – carcinogenic (causing cancer), mutagenic (causing mutation) and reprotoxic (toxic to reproduction). The influence of CMR substances can increase the risk of formation of malignant tumours and mutations as well as cause reproductive system problems, affecting the offspring

5.2. Global environmental pollution problems

5.2.1. Earth's ozone layer and the consequences of its depletion

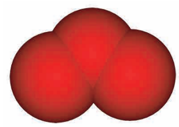


Figure 5.2. Ozone molecule is composed of three interconnected oxygen atoms

Ozone (O_3) is one of the oxygen molecule forms composed of three interconnected oxygen atoms. Ozone is a pale blue gas that has a higher density than air. Ozone is formed when energy – for example, electromagnetic radiation – splits the oxygen molecules. As a chemical substance, ozone is a powerful oxidant. The presence of ozone in the atmosphere, its formation and disintegration reactions are vital for the absorption of the UV radiation from the Sun.

The ozone concentration near the Earth's surface is ~0.001% by volume, whereas in the stratosphere its concentration may be even more than 100 times higher. Nonetheless, the ozone concentration in the stratosphere is relatively low because the air in this layer of the atmosphere mostly consists of nitrogen (78%), oxygen (21%) and argon (~1%). The ozone layer (its thickness in the atmosphere under normal conditions is approximately 2.5 mm if only the dispersed ozone molecules were gathered together) protects the biosphere from the ultraviolet part of the solar radiation spectrum. The ozone concentration in the atmosphere mostly depends on the latitude, season, solar activity and other factors. The ozone layer is thickest at the height of 25-30 kilometres in equatorial regions and 15-20 kilometres around the Earth's poles (Figure 5.3).

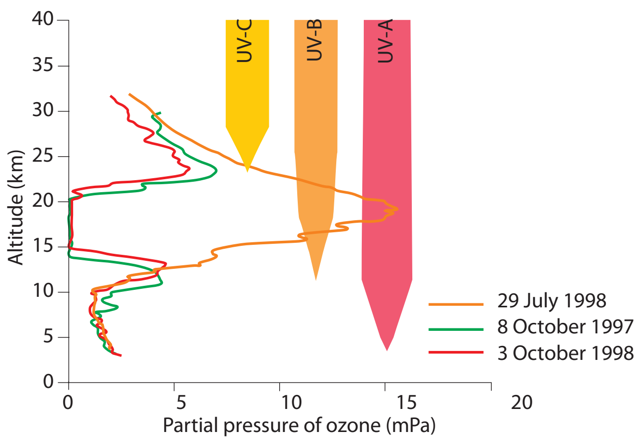


Figure 5.3. Variability of the ozone concentration over the Antarctic and the absorption of UV radiation in the atmosphere depending on the UV radiation wavelength

In the first stage of ozone molecule synthesis, an oxygen molecule is excited by absorbing the UV radiation energy (Figure 5.4). The excited oxygen molecule splits into two oxygen atoms that are free to react with another oxygen molecule to form an ozone molecule. In this way, UV radiation is absorbed during the ozone molecule formation process, and the new ozone molecule also is capable of absorbing it. At the same time, UV radiation that has a shorter wavelength (and higher energy) splits the ozone molecules. As a consequence, the concentration of ozone is decreasing in the upper layers of the atmosphere. Thus, the Earth's ozone layer is a region in the atmosphere where the reactions of ozone molecule synthesis and destruction are in a state of a certain equilibrium (destruction reactions prevail in other parts of the atmosphere), whereas higher concentrations of ozone are present in the stratosphere.

The ozone concentration in the atmosphere is expressed in gas concentration units of measure (mg/m³, µg/m³) or in a special unit of measure called the Dobson unit (DU) in honour of Gordon Miller Bourne Dobson, who was one of the first scientists studying the atmospheric ozone. One Dobson unit is a 0.01 mm thick ozone layer under standard temperature and atmospheric pressure.

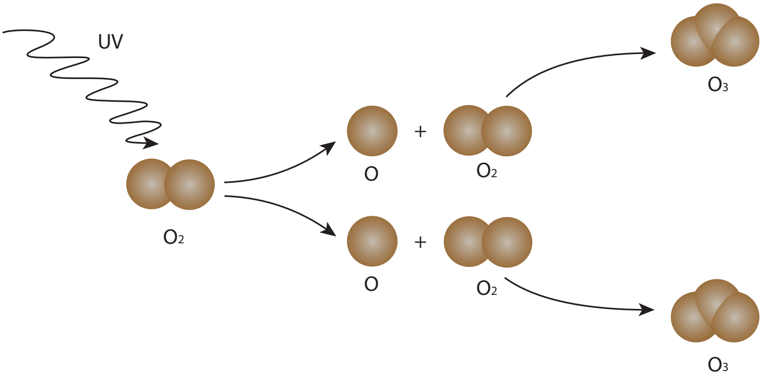


Figure 5.4. Ozone molecule formation induced by UV radiation

Several factors affect the concentration of ozone: the movement of air masses, natural, seasonal and other processes. The anthropogenic contamination of the atmosphere has a crucial role in the ozone layer destruction processes. The atmospheric contamination with halogenated hydrocarbons, produced in relatively large amounts, is considered to be particularly hazardous to the environment (Table).

Table. **Main substances that affect the ozone layer**

Substance	*Usage*	*Lifetime in the atmosphere, years*
Freons, CFC – 11 $CFCl_3$	In aerosols, refrigerant	55
CFC – 12 CF_2Cl_2	In aerosols, solvent	116
CFC – 22 $CHFCl_2$	Solvent	400
Chloroform, $CHCl_3$	Solvent, reagent	0.7
Carbon tetrachloride, CCl_4	Solvent, in firefighting	4.7
Nitrogen oxides, NO_x	In industry, energy	A couple of days
Methane, CH_4	In agriculture, industry	10.5

Halogenated hydrocarbon molecules are composed of carbon, hydrogen and halogen (F, Cl, Br, I) atoms. Those halogenated hydrocarbons whose molecules contain one or two carbon atoms and have their remaining hydrogen atoms replaced by fluorine or chlorine atoms are called freons. Considering the wide range of industrial use of these substances, their production in industrial quantities began in the 30s of the 20th century. Initially freons were used as a replacement for such hazardous and toxic gases as ammonia (NH_3) and sulphur dioxide (SO_2) in refrigerators. Since freons had low toxicity and were non-combustible, they were found useful in a wide range of other applications as well. At the end of the 1980s, the total production amount of freons reached 1.2 million tons per year.

Freons are emitted into the environment as a result of specific features of technological processes (e.g., refrigeration systems), after use of products (e.g., aerosols) and in technological processes (e.g., microchip cleaning). The lifetime of freons in the atmosphere is from 29 to 500 years. After entering the stratosphere, freons interact with UV radiation, releasing chlorine or fluorine atoms that can subsequently become involved in ozone degradation reactions.

The reduction of the ozone concentration (the ozone layer depletion) was observed for the first time over the Antarctic, where natural processes initiate an especially intensive breakdown of ozone molecules (Figure 5.5). At the beginning of the 1970s, the size of the Antarctic ozone hole was a few million square kilometres, while now it exceeds 25 million square kilometres.

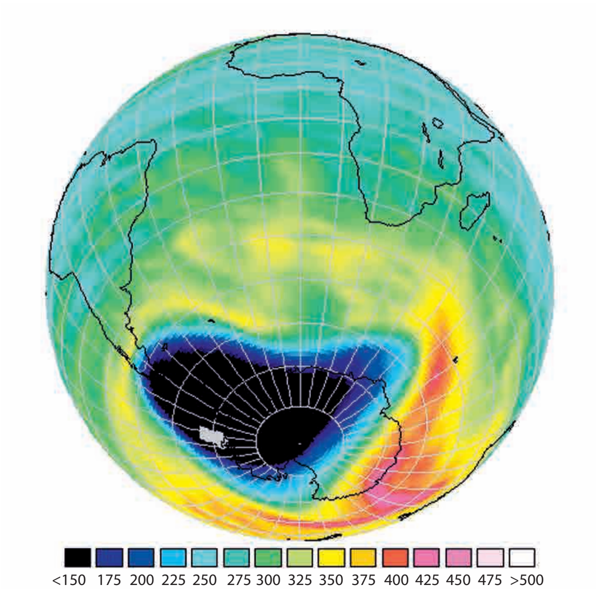


Figure 5.5. Profile of the ozone hole over the Antarctic (ozone concentration in Dobson units)

The decrease in the ozone concentration in the stratosphere increases the intensity of UV radiation reaching the Earth's surface. UV radiation is divided into three radiation ranges with different wavelengths according to its biological effect: UV-C (wavelength λ <290 nm); UV-B λ= 290-320 nm) and UV-A (λ= 320-400 nm). UV-A and UV-B radiation reaches the Earth's surface. Window glass, for example, absorbs most of this radiation. UV-C and a significant part of UV-B radiation is absorbed in the stratosphere.

The depletion of the ozone layer by 5% will substantially increase the intensity of UV-B and UV-C radiation reaching the Earth's surface. It is estimated that the mortality rate from malignant skin diseases will increase by 20%. Increased UV radiation can affect the immune system, vision, cataract may become pervasive. The intensity of UV radiation may have an effect on the agricultural production and on the reproduction of living organisms in the World Ocean, especially plankton. Reduction in the growth of plankton, in turn, will affect the fish feed base. Furthermore, the impact on the Earth's thermal balance may also be considerable.

The depletion of the ozone layer and increase in the intensity of UV radiation reaching the Earth's surface have far-reaching consequences. Diminishing the negative effects of UV radiation has become one of the central objectives of environmental protection policy. Suntan has for a long time been regarded as a sign of a healthy lifestyle and good health in general. However, today views about the healthfulness of sunbathing have radically changed. The production and use of various sunscreen cosmetic products and sunglasses that protect the skin and the eyes from UV radiation has been increasing.

Several legislative acts have been adopted with the aim to reduce the destructive effects of pollution on the ozone layer. The drafting of legislation pertaining to the ozone layer protection began in 1985. The most important international treaty in this regard is the Montreal Protocol on Substances That Deplete the Ozone Layer (a protocol to the Vienna Convention of 1985 for the Protection of the Ozone Layer) designed to restrict the production of these substances.

To a considerable extent, the legislation restricting the ozone layer depletion had laid the foundations for further development of an effective environmental law system. The environmental legislative acts drafted for the purpose to restrict the use of substances that destroy the ozone layer provide for various activities carried out on an international level, such as the ozone layer study and monitoring, phasing out the production of these substances, compensations to developing countries for the losses incurred due to the high costs of alternative technologies. The implementation of the relevant international laws has been successful – the use of ozone-depleting substances has been significantly reduced (Figure 5.6), and alternative solutions have been developed in the sectors where the use of substances with properties analogous to freons is necessary. There are reasons to believe that the ozone layer recovery has already begun (this is also confirmed by recent measurements of the ozone layer), and the concentrations of ozone-degrading substances in the atmosphere may noticeably decrease in the future.

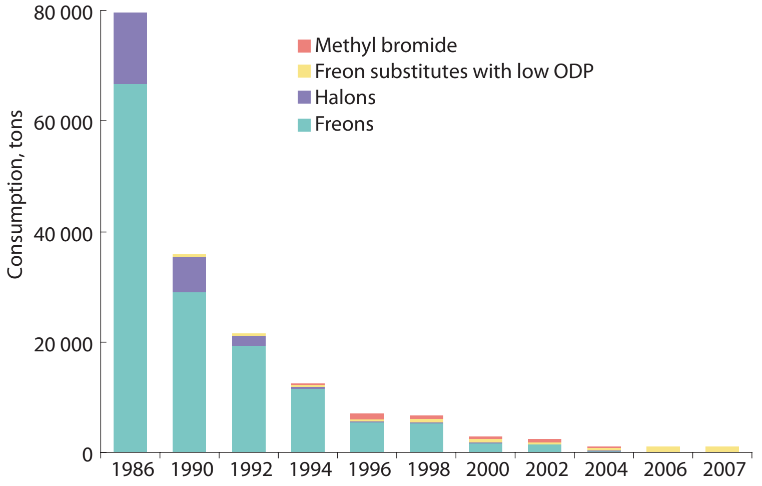


Figure 5.6. Changes in the production amounts of ozone-depleting substances in the EU Member States

5.2.2. Global warming

Climate is the statistical summary of weather and meteorological phenomena and occurrences over a long period of time, ranging from a few years or decades to thousands of years. Climate is expressed in averaged long-term atmospheric physical parameter values characteristic of the Earth as a whole (global climate) or of a specific territory (a country or region). Like many other issues relating to climate change, the extent and character of human influence on climate are still studied and analysed, but, to say the least, there is no doubt that human activities do influence climate.

There is conclusive evidence that the consequences of human activities – such as air, water and soil pollution, overpopulation – also cause climate change. However, it is quite difficult to distinguish clearly and unambiguously the climate change processes stimulated by human activities from those that are part of natural development. A sharp increase in the concentration of various gases (their source is human activity) in the atmosphere is indicative of the increase in anthropogenic influence (Figure 5.7). It is evident from the diagram that the concentrations of gases were considerably lower in the period when industrial production was not yet intense, while they have substantially increased during the last centuries.

The concentration of greenhouse gases has increased just within the last 300 years – beginning with the Industrial Revolution. There are reasons to believe that the sharp increase in environmental pollution since the beginning of industrialisation has been affecting climate change. Consequently, the current climate change process could be untimely and unnatural, and it may also lead to many global climate problems that we already witness today.

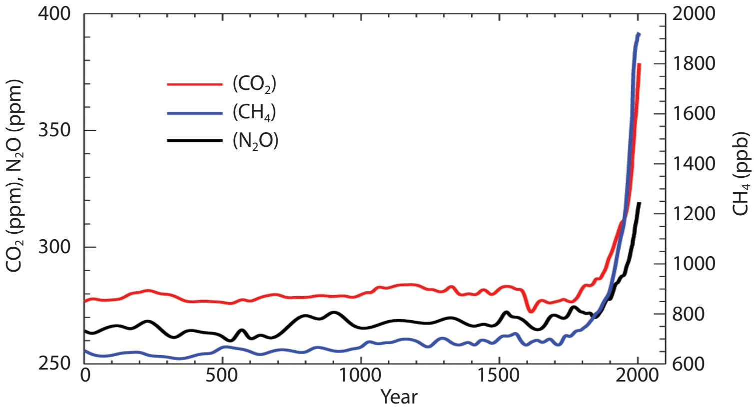


Figure 5.7. Changes in the concentrations of carbon dioxide (CO_2), nitrogen(I) oxide (N_2O) and methane (CH_4) in the atmosphere during the last 2000 years

The phrase 'global warming' denotes not only the increase in the Earth's average temperature (Figure 5.8), usually measured as the average temperature per year, but also substantial changes in the entire climate system.

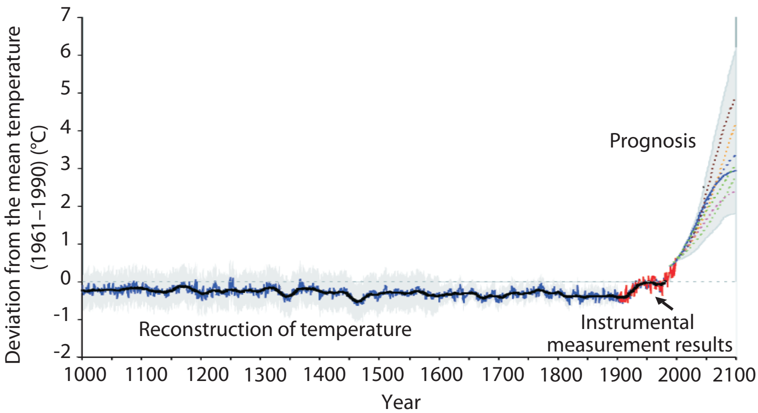


Figure 5.8. Temperature changes in the Northern Hemisphere during the last 1000 years and a prognosis of possible changes in the future

The climate in the Baltic countries has become warmer over the last years. Winters have become shorter and the snow cover thinner. The warm period has become longer, and there are fewer days with low temperatures. The average temperature on the planet has increased for approximately 0.7 ± 0.2 °C (Figure 5.9). Long periods of draught occur in summers. Air warming takes place not only over the continents but also over the seas and oceans. With the increase in temperature, the snow cover duration is decreasing. Air warming is related to the reduction of permafrost areas. Mountain glaciers recede to higher elevations and become smaller and shorter, affecting the mountain rivers. As glaciers melt and the snow cover diminishes, the global sea level is rising.

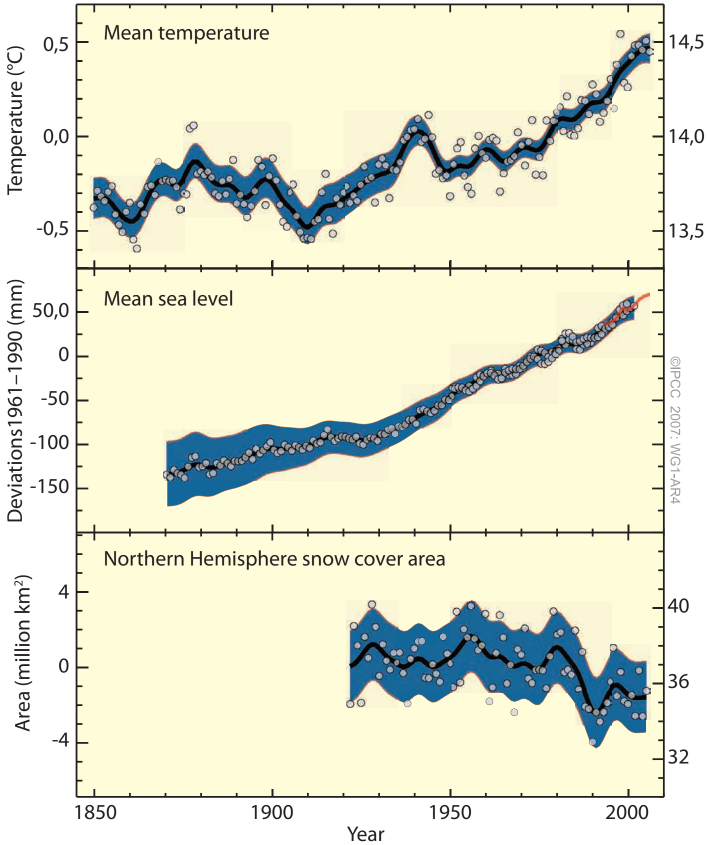


Figure 5.9. Changes in the air temperature, sea level and snow cover area within the last 150 years

Temperature rise in the Northern Hemisphere and particularly in the Baltic Sea Region does not occur evenly throughout the year; for the most part, only the winter months have become warmer (Figure 5.10).

The effects of global warming are not equally intense in all regions of the Earth. Global warming has affected the rainfall patterns – they have recently become more irregular, leaving some regions with almost no precipitation and causing long drought periods, while elsewhere rainfalls have become much more frequent than before. In some regions, such as China, long drought periods alternate with severe floods, seriously impeding the agricultural production.

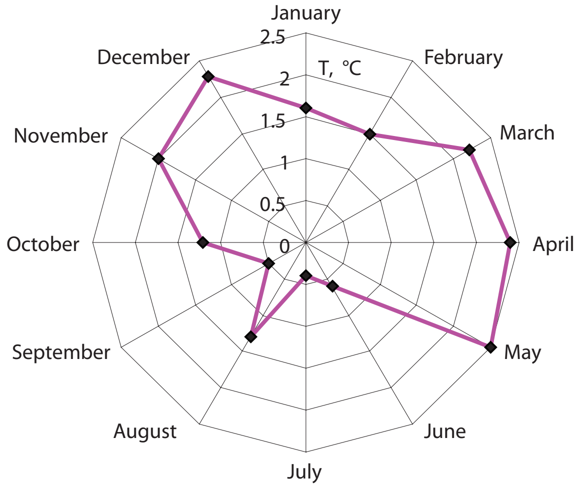


Figure 5.10. Average monthly temperature rise in Rīga (1851-2008 I-XII)

Precipitation is the source of freshwater which flows into the seas and oceans, changing the freshwater and saltwater proportion. These changes, in turn, affect the warm ocean current patterns. The mean sea level rises due to the increased precipitation and the melting of glaciers, ice cups and ice sheets. As a consequence, the habitable dry land areas decrease. Global warming and the related climate change can also cause serious economic problems. Climate change can seriously impede the agricultural production. The mean air temperature increases and unstable winters affect the plant kingdom. Due to the warm weather, many plants start to bloom earlier in spring and are destroyed by sudden frosts. Although late frosts have also occurred before the major climate change, in present-day warm winters the plants break into leaf well before spring begins. Many countries of the world that base their economies mostly on agriculture incur losses and may even face an economic crisis due to climate change. The irregularity of rainfall also causes serious damage, since both heavy rains and draught badly affect crops. The developing countries that have not accumulated sufficient reserves for emergencies may experience even greater problems with providing living means to their residents.

Variability of climate systems can be projected with the help of climate models used when it is impossible to study an object or phenomenon directly.

All the issues related to the Earth's climate change are interrelated – when the air temperature changes, the rainfall and global sea level will also change, and each of the factors will affect the others. This principle is underlying climate change modelling.

The increase in global warming largely depends on greenhouse gas concentrations and emission amounts. Therefore, to forecast the temperature, we need to forecast the gas emission amounts, which, in turn, depend on the lifestyle of humans. The United Nations Intergovernmental Panel on Climate Change has developed several alternative models for the prospective development of society and climate change:

- Scenario A1 ('zero' growth). Greenhouse gas concentration in the atmosphere remains at the level of 2000; there is no economic and population growth, and climate change is driven by the climate system inertia only.
- Scenario B1 (sustainable development). Natural growth continues until the middle of the 21st century, then the population declines; the economic development continues.
- Scenario A2 ('business as usual'). This scenario describes a differentiated world, in which each nation relies on its own powers and resources; the population is constantly growing; economic development is regionally-oriented.
- Scenario A1B (technological progress). This scenario describes a world of rapid economic development, population growth and technological progress that allows to reduce the consumption of material resources.

The climate change future scenarios predict that the air temperature will rise by 1-8 degrees on average, and the warming rate is projected to be higher than it was in the 20th century (Figure 5.11). Global warming will definitely affect the average rainfall on the

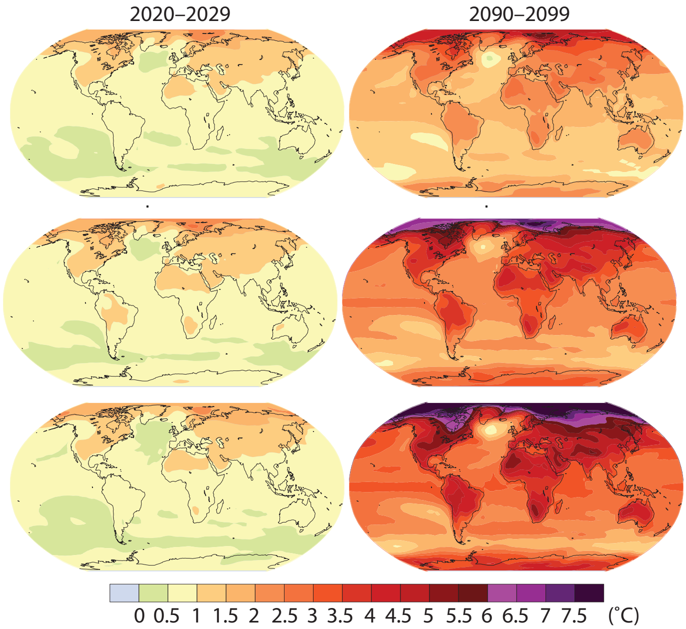


Figure 5.11. Modelled mean air temperature on the Earth

Earth (Figure 5.12). Along with the increase in temperature, the moisture concentration and hence rainfall will also increase. Precipitation will not be regular, and there will be a risk of drought periods in many regions of the Earth. Rainfall changes can affect the Earth's processes, for example, heavy precipitation in polar regions may affect the stability of glaciers and ocean currents.

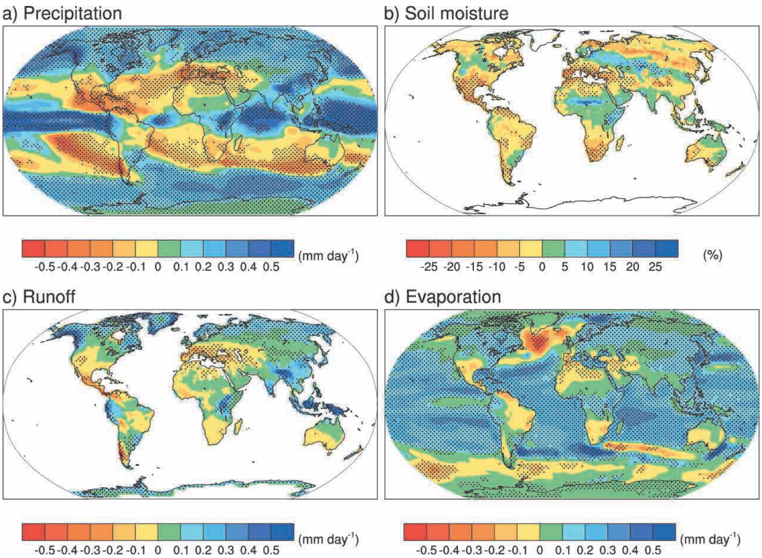


Figure 5.12. Projected rainfall changes Mean changes in (a) precipitation (mm day^{-1}), (b) soil moisture content (%), (c) runoff (mm day^{-1}) and (d) evaporation (mm day^{-1}). Changes are annual means for the A1B scenario for the period 2080 to 2099 relative to 1980 to 1999. Soil moisture and runoff changes are shown at land points with valid data from at least 10 models.

The mean air temperature on the Earth is modelled for the periods between 2020 and 2029 and between 2090 and 2099 vis-à-vis the temperature in the period between 1980 and 1999, depending on the potential society development and climate change scenarios: B1; A1B; A2 (from top to bottom). The figure shows how the air temperature on the Earth can change depending on the society development scenario.

Both rainfall changes and global warming affect the global sea level. It hardly needs saying that, as the Earth's temperature rises, the ice sheets of the polar region begin to melt, and it turns out that the permafrost boundary is not permanent at all. This melting causes the water level in oceans to rise. The climate change models project that, until 2100, the water level in seas and oceans will have risen by 0.09 to 0.88 metres (Figure 5.13).

This figure shows the actual and possible changes in the water level in seas and oceans in the period between 2000 and 2100.

The mean water temperature in the oceans and seas will also increase, which means that the melting of glaciers and ice sheets and the rise of the sea and ocean levels will continue for hundreds of years after the stabilisation of greenhouse gas concentrations. With that, the inhabitable dry land areas will decrease. With the melting of polar ice, large amounts of freshwater will flow into the oceans and seas, affecting the marine fauna, ocean currents and thermal balance.

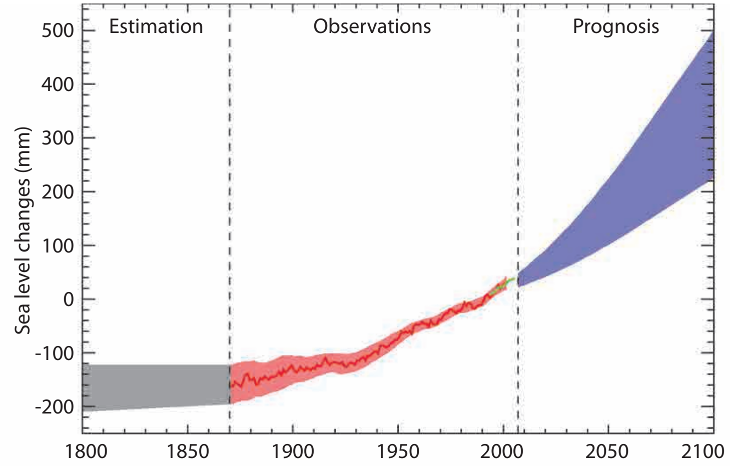


Figure 5.13. Confirmed and projected sea level changes

It is worth noting that climate change cannot be projected accurately because there is also a possibility that these processes occur faster, by leaps, causing global cataclysms.

5.3. Regional environmental pollution effects

5.3.1. Sulphur compounds

Today the main source of sulphur compounds in the atmosphere is human economic activity. In 2006, it created approximately 65% of the total amount of sulphur compounds in the atmosphere, and sulphur dioxide (SO_2) made up 90% of this amount.

Sulphur is quite a widespread element on the Earth, and most of the sulphur compounds are found in the lithosphere and hydrosphere. The emission of sulphur compounds into the environment has considerably increased since the beginning of intensive human economic activity associated with the industrial revolution. The main processes in which sulphur compounds are released from the lithosphere are ore extraction (several metals are found in the form of sulphide and sulphate ores), fuel (coal, oil, peat) combustion and fertiliser production. The main source of sulphur dioxide emission is energy production, i.e. energy production by combusting different fuels. Both the combustion process and fuel quality can significantly affect the intensity of pollution. Coal combustion releases into the atmosphere about 70% of the total anthropogenic emissions. In the Baltic states, the main sources of sulphur dioxide are the so-called stationary emission sources or power plants, of which the Narva Power Plant (Estonia) complex is the leading one. Although in the European Union countries the total SO_2 emission levels have considerably decreased in recent decades, they are still comparatively high (Figure 5.14).

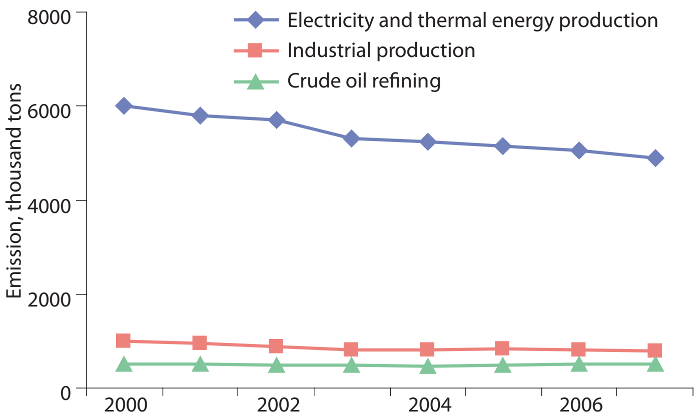


Figure 5.14. Changes in the total sulphur dioxide emissions in the EU Member States

The main anthropogenic source of sulphur dioxide is fossil fuel combustion (Figure 5.15).

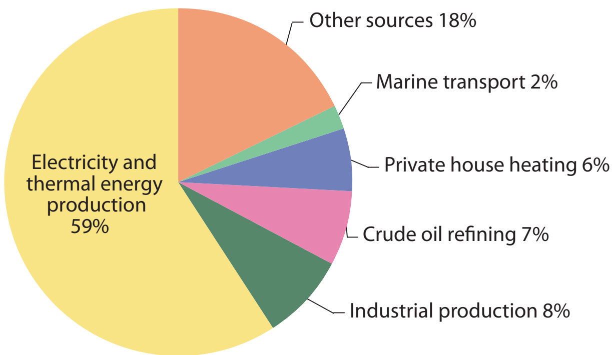


Figure 5.15. Sulphur dioxide emissions according to their sources in the EU Member States (2007)

Sulphur dioxide is a colourless gas with a very strong, pungent odour. It is easily liquefiable and soluble in water, making a medium-strong acid – sulphurous acid (H_2SO_3). Sulphur dioxide oxidises easily in the atmosphere, reacts with atmospheric water vapour, and sulphuric acid solution is the end-product of these transformations. The fallout of compounds formed as a result of sulphur dioxide oxidation occurs in the forms of rain and snow (wet deposition) as well as dust (dry deposition).

In high concentrations, sulphur dioxide causes severe respiratory irritation. Since sulphur dioxide is soluble in water, when breathed in, it can already be sorbed by the nasal and airway mucosa, whereas sulphur dioxide penetrates the lungs. This is one of the factors causing the harmful effects of smog, as it is formed in humid air and has a high dust content.

When the daily average concentration of sulphur dioxide reaches 500 $\mu g/m^3$, it aggravates the condition of people suffering from asthma and pulmonary diseases, whereas an increase in hospitalisation rate has been observed at concentrations reaching 750 $\mu g/m^3$. The sulphur dioxide concentration in the air reached 4000 $\mu g/m^3$ during the London Great Smog of 1952.

Sulphur dioxide also adversely affects plant growth. High concentrations of sulphur dioxide can cause necrosis or death of plant tissue, while chlorosis – pale, yellow or yellow-white leaves because of insufficient chlorophyll – is characteristic of chronic exposure. The harmful effects of sulphur dioxide are amplified with increasing humidity. Sulphur dioxide inhibits the photosynthesis and respiration process in plants and causes damage to cell membranes. The extent of plant damage depends on the balance of nutrients and trace elements and also on the presence of alkaline compounds in the soil in which the plant is growing. The indirect effects of sulphur dioxide – causing environmental acidification because of a drop in the pH level of precipitation – affect the condition of plants and forests, as well as aquatic ecosystems and processes taking place there.

5.3.2. Nitrogen compounds

Nitrogen makes up approximately 76% of the mass of the atmosphere. Several nitrogen oxides can also be present in the atmosphere as air pollutants: nitrogen(I) oxide N_2O, nitrogen(II) and (IV) oxides NO, NO_2 and even nitric acid HNO_3.

Nitrogen(I) oxide N_2O is formed mainly through natural processes, and human activity affects its concentration only indirectly. This substance is odourless, tasteless and chemically inert. It is used as an anaesthetic agent in medicine and as an inert gas in technological processes. No toxic effects of this substance have been found.

From the environmental pollution standpoint, special attention should be given to nitrogen(II) oxide NO and nitrogen(IV) oxide NO_2. Nitrogen(II) oxide NO is a colourless, odourless and non-flammable gas. Since it is easily oxidised to NO_2 in the air, usually the combination of these two oxides resulting in NO_x or flue gas is considered. Nitrogen(II) and nitrogen(IV) oxides are highly toxic. Nitrogen(II) oxide is formed when the gases constituting the atmospheric air mutually react at increased temperatures. The rate of this reaction depends on the temperature, respectively, on the amount of energy supplied. NO is already forming, for example, when reaching incandescence. The reaction of NO, N_2 and O_2 molecules is in a state of equilibrium at a temperature of 2000 °C. The intensity of the NO formation process is affected by how soon the created molecule leaves the reaction zone. In any case, nitrogen oxides are formed in all processes that take place at high temperatures, e.g. in plasma and in combustion and explosion processes.

Nitrogen oxides are also formed in the combustion processes of motor vehicle engines. Intensive release of nitrogen oxides during the process of electrical welding, especially in confined premises, is unsafe from the viewpoint of work safety. Emitted in the stratosphere, nitrogen oxides can participate in the ozone breakdown cycle. Supersonic aircraft exhaust is a significant source of nitrogen oxides in the stratosphere.

The oxidation of nitrogen oxides in the atmosphere forms nitric acid HNO_3, fallout of which occurs with precipitation mainly in the forms of acid and salt. Nitric acid, together with sulphur compounds, causes the acidification of precipitation and the environment. Since the transformations of nitrogen oxides and their elimination from the atmosphere occur quite swiftly, the acidification of precipitation caused by nitrogen compounds significantly affects the areas near the contamination sources.

Today the emission of nitrogen oxides as well as another environmental pollutant – ammonia – has become, overall, one of the most hazardous environmental pollution factors in Europe. Although the emission levels have been notably reduced, they are still high (Figure 5.16).

The issue concerning the reduction and control of the emission of nitrogen oxides becomes particularly acute in the Baltic Sea Region countries, where the concentrations of nitrogen compounds stimulate many negative processes occurring in the region.

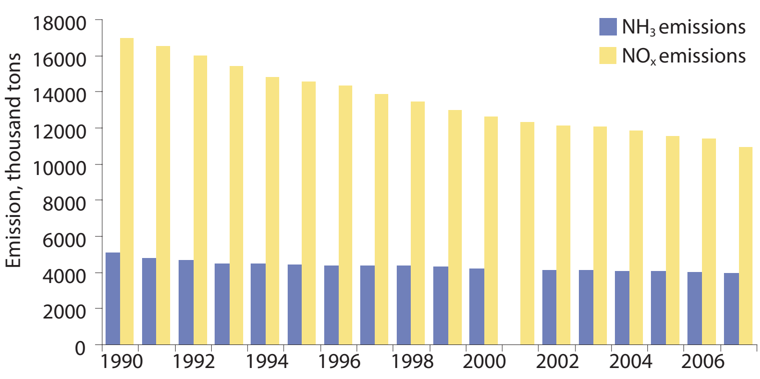


Figure 5.16. Emission amounts of nitrogen oxides and ammonia and their changes in the European Union Member States

Motor traffic is considered one of the major sources of nitrogen oxides which directly affect the air quality in cities (Figure 5.17).

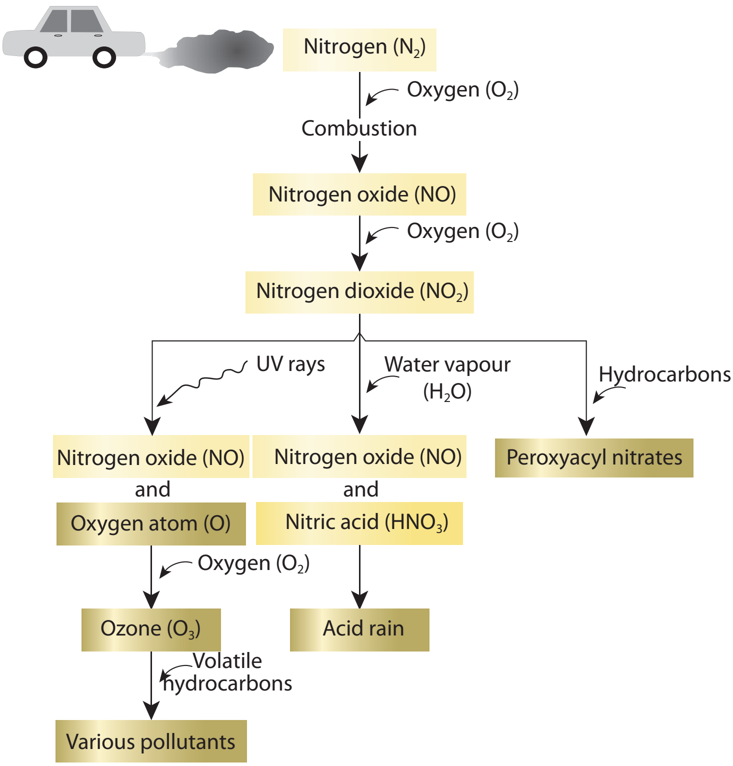


Figure 5.17. Role of nitrogen oxides emitted with motor vehicle engine exhaust in the reactions of formation of smog, acid rain and ozone

5.3.3. Dust and aerosols

Atmospheric air contains particles of every sort, size and composition. Their sizes may vary from micron to millimetric parts. The finer particles (size <10 µm) are called aerosols, whereas the coarser are called dust. Liquid micro-droplets (haze) are also counted as aerosols. The main sources of dust and aerosol formation are various natural processes – soil and its constituent mineral particles entering the atmosphere with wind, dust storms (Figure 5.18), volcanic eruptions, forest fires, and evaporation from the sea and ocean surfaces (forming sea salt aerosols). Admittedly, today human activity causes the discharge of many aerosols and dust into the air. The main anthropogenic sources are such processes as the generation of energy, the production of building materials, mining, agriculture, air transport and others.

Figure 5.18. Sand storm in the Sahara

Aerosols can be formed and the composition of particles in the air can vary as a consequence of different chemical reactions. Sulphur and nitrogen oxides play a considerable role in these processes. Since the airborne solid particles form the condensation centres for water vapour, all these reactions take place in the atmosphere in the presence of water. Acid rain formation is a typical example.

As aerosols and dust particles have a relatively large surface, they can sorb atmospheric gases, chemicals, micro-organisms and water vapour, and this sorption process determines the rather complex composition of aerosols.

Atmospheric aerosols and dust can significantly affect the Earth's climate, as evidenced by long-term climate change analysis and the increasing effect of dust from volcanic eruptions on the climate.

An important group of aerosols are those of organic composition. Their source can be both natural processes (plants, forest fires, organic matter decay) and anthropogenic processes. The presence of metal compounds (Pb, Hg, Cu, Ni, Be), radioactive isotopes and organic substances in the composition of aerosols can particularly adversely affect the human health. The exposure to aerosols is most hazardous in case of inhaling such particles that are retained in the lungs (coarser dust particles are captured in the nasal cavity and upper airways, whereas finer particles can be exhaled). The aerosols containing such particles are called respirable aerosols. Their particle sizes are often smaller than 2.5 μm. These aerosols are designated $PM_{2.5}$ (PM stands for Particulate Matter). The effects of these aerosols can be as follows:

1) the substances adsorbed on the surfaces of aerosol particles may desorb and enter the circulatory and lymphatic systems. Such

an effect is typical of various combustion products. Combustion product aerosols contain carbon, and on the surface of these aerosols, usually there is quite a high concentration of different organic substances originated from incomplete combustion or in the process of thermosynthesis;

2) ultrafine particles, such as asbestos fibres, can penetrate the blood or lymphatic system from the lungs;
3) aerosol particles can remain in the lungs and calcify, causing constant irritation. The aerosol effect of this type is characteristic of occupational diseases – asbestosis and silicosis, caused by inhaling the air polluted with mineral particles;
4) micro-organisms, bacteria or fungi residing on the aerosol and dust particles may cause allergic reactions as well as illness.

The dust of pollen, wood, flour and other organic substances can be considered a special group of aerosols. Since these substances are organic, their composition differs significantly from the traditional dust composition; yet, these aerosols can cause allergies.

Since the effects of aerosols on humans, animals, plants and buildings can be detrimental, and aerosols and dust can be considered, by their mass, the largest group of atmospheric pollutants, it is crucial to limit their emission in the main sectors responsible for this kind of pollution, namely the production and energy industry.

5.4. Indoor air pollutants

Air pollution is usually associated with the quality of outdoor urban air. However, the health of humans may be much more affected by air pollution in their living environment – dwelling and working premises (Figure 5.19).

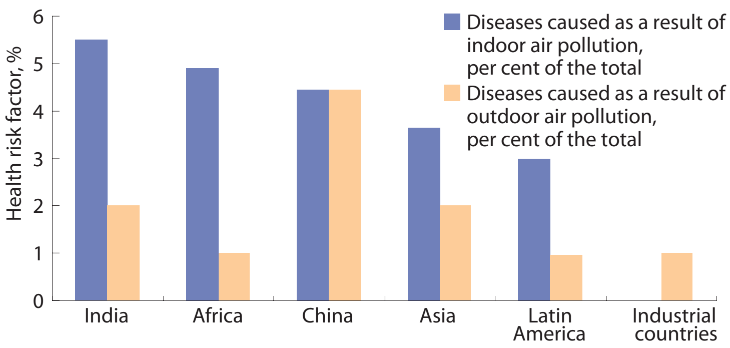


Figure 5.19. Relative impact of indoor and outdoor air pollution on the human health in different regions of the world

There are several factors that determine indoor air pollution. First, there is the air pollution in human living environment caused by the external air inflow. An example of such a situation is an excessive concentration of lead and polyaromatic hydrocarbons in dwelling premises near motorways. Second, different local sources – such as kitchens, stoves, furniture, polymer materials, painted surfaces, animals – may also cause serious indoor air pollution.

Another factor that affects the indoor air quality is the production of new materials and substances. In this way, increased quantities of new substances are brought into the human living environment, contaminating it. For example, new insulation materials, cleaning agents, cosmetic products, solvents, plant protection products expose humans to the substances whose toxic properties have been proved. Pollution of human living environment can cause a variety of adverse effects, including instant death. Quite often people die from poisoning with carbon monoxide emitted from stoves, fireplaces and gas heaters. Even in developed countries indoor pollution may be fatal, as evidenced by the deaths from legionellosis.

However, long-term effects of living environment pollution on the human health are considerably more common. These effects can manifest themselves after longer periods of time, even decades; hence, it is difficult to prove them using today's research methods (such as epidemiological study results). Such effects are characteristic of such substances as radon, asbestos, formaldehyde and others. Moreover, today the air pollution in dwelling premises is considered one of the main causes of certain illnesses, for example, lung cancer.

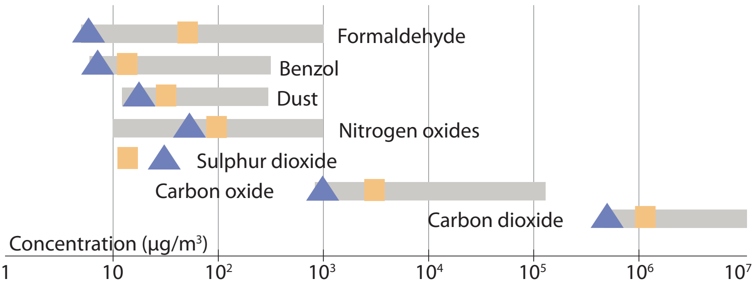


Figure 5.20. Comparison of typical concentrations of indoor (■) and urban environment (▲) air pollutants and the concentration intervals in the indoor air (▬)

Air environmental pollution can be caused by both organic and inorganic substances as well as micro-organisms. Legionnaires' disease – a more severe form of the illness known as legionellosis – is a typical illness caused by the living environment air pollution with micro-organisms, in this particular case – by the bacteria *Legionella pneumophila*, which is one of more than 20 similar bacteria that cause legionellosis.

Outbreaks of legionellosis have occurred in 1981, 1985, 1988, 1992 in the USA as well as other countries, and, having regard to the high fatality rate from this disease, it has been studied quite extensively. Legionellosis is a lung disease caused by environmental pollution (it does not spread from person to person) with the bacteria. These bacteria thrive in water, particularly in closed water circulation systems, ponds, also in air conditioning systems, and they can be inhaled in the form of aerosols when water is disseminated, for example, by showers, garden sprinklers, humidifiers and other equipment. As aerosols bacteria can be transmitted to relatively long distances. To prevent legionellosis, it is important to set up and operate water circulation systems properly. Practically, it means preventing the reproduction and growth possibilities for bacteria.

Allergic alveolitis can also be caused by micro-organisms in the air. Alveolitis in its acute form begins six to eight hours after exposure, and it has the symptoms of an acute respiratory illness, such as fever, shortness of breath, cough and muscle pain. The sickness may last just a few days if exposure to the provoking antigen ceases. The chronic form of the disease is more common in the presence of a constant low-level pollution source, for example, domestic animals. This disease is caused by the fungi, which, for that matter, also cause an allergic reaction to hay, especially if it is mouldy. The same micro-organisms can also thrive in air-conditioning and ventilation systems.

The presence of fungi, bacteria and other micro-organisms in the indoor air can also cause such diseases as asthma, allergic rhinitis and the sick building syndrome. The latter has a number of different symptoms that people may experience while they are living or working at particular premises and that cease when they leave these premises. Typical symptoms of this syndrome are irritated and watering eyes, running nose, headache and sometimes asthma. Air conditioning and humidification systems can also cause infectious diseases.

Air pollution with asbestos typically occurs only in the human working and living environment. Asbestos is a generic term for fibrous silicate minerals. The environment can be contaminated by using asbestos cement, asbestos fabrics and asbestos as a heat insulation material. The hazardous effects of exposure to asbestos are caused by its mechanical action on the living tissue with which it comes into contact. In the case of inhaling the air contaminated with asbestos, a relatively large part of its fine fibres is lodged in the lungs. Prolonged exposure to asbestos dust may cause asbestosis – a pulmonary fibrosis caused by asbestos inhalation, associated with pleural calcification and a possibility of developing into lung cancer. Asbestosis has a very long latency period – 14 to 35 years.

Another pollutant affecting, first of all, indoors and working environment is radioactive radon (Rn). Radon is a colourless noble

Since people in developed countries spend indoors approximately 70% of their time, the indoor air quality should be given special attention. The living environment air pollution with asbestos has been widely studied, proving its adverse effects on the human health. However, the artificially produced fibrous materials (glass wool, glass fibre, rock wool), especially when they have deteriorated, may cause similar pollution. Air contamination in living rooms with the chemicals typical of outdoor air pollution – such as sulphur oxides, heavy metals, aerosols – also is a matter of great concern.

gas, denser than air, formed naturally as an intermediary product in the decay process of such radioactive elements as uranium (^{238}U) or thorium (^{232}Th). Condensed radon has a blue glow. As gas radon is an inert substance, which is not retained in the human body. Radon is hazardous due to the action of atoms separated in its breakdown process while the gas is in the lungs. Radon decay products are reactive metals that form oxides and other compounds that are deposited in the human body. Since these compounds are unstable and disintegrate further, in this way the human body becomes exposed to internal ionising radiation. In most cases, the effect of this radiation is the development of malignant tumours (primarily lung cancer). Swedish scientists estimate that in Sweden up to 25% of death occurrences from lung cancer are caused by radon. Indoor radon contamination is a typical human living environment pollution problem, because high concentrations of radon can occur only in confined spaces with limited air circulation. Up to 80% of radon emission comes from soil and the rock weathering process. Since radon as gas is very penetrating, it enters into the human living environment through cracks and openings in building foundations. Drinking water can also be a major source of radon.

In conclusion, considering the substantial effect of indoor air quality on the human health, the range of issues associated with air pollution in human living environment deserves special attention.

References

Baird C., Cann M. (2005) Environmental Chemistry. N.Y.: W. H. Freement and Company.

Berner E. K., Berner R. A. (1996) Global Environment: Water, Air and Geochemical Cycles. N.Y.: Prentice-Hall.

Botkin D., Keller E. (2000) Environmental Science: Earth as a Living Planet. N. Y.: John Wiley and Sons.

Jacobson M. Z. (2002) Atmospheric Pollution: History, Science and Regulation. Cambridge: Cambridge University Press.

O'Hare G., Sweeney J., Wilby R. (2005) Weather, Climate and Climate Change. London: Pearson Education.

Air Quality in Europe. Accessible: *www.airqualitynow.eu/*.

Air Quality in the EU. Accessible: *http://ec.europa.eu/environment/air/index_en.htm*.

European Environment Agency. Accessible: *www.eea.eu.int*.

European Monitoring and Evaluation Programme. Accessible: *www.emep.int*.

Indoor and Outdoor Air Pollution. Accessible: *www.lbl.gov/Education/ELSI/pollution-main.html*.

Ozone Internet Resources. Accessible: *www.ciesin.org/TG/OZ/oz-net.html*.

United Nations Environment Programme. Accessible: *www.unep.org/themes/ozone/*.

US EPA. Accessible: *http://www.epa.gov/ozone/strathome.html*.

World Health Organisation. Accessible: *www.who.int/topics/en*.

World Health Organisation. Accessible: *www.who.int*.

6. ACTION OF TOXIC SUBSTANCES IN THE ENVIRONMENT – BASIC CONCEPTS OF ECOTOXICOLOGY

6.1. Concept of ecotoxicology

The existence and development of humankind has become dependent on the quantity of chemical substances that are used in various production processes and households. Substances essential for everyone are polymers, plant protection agents and pharmaceuticals. They are used in clothing manufacture, construction, agriculture, household, and their use has made it possible to improve the human life quality and to extend the lifespan significantly. We can argue that the production of any chemical substance is associated with both the benefits from its use and the risk that may be caused by its adverse properties. Human health can be affected not only by the use of chemicals but also by various physical factors, such as electromagnetic radiation, noise and heat. The electromagnetic radiation of high energy and short wavelength (γ-radiation) can destroy the structure of cells, influence the biomolecules which determine reactions taking place in the body. Therefore, exposure to high doses of this radiation is lethal to humans. Electromagnetic radiation of longer wavelengths (200-400 nm) (ultraviolet radiation) can cause skin pigmentation (tanning), but lasting exposure to this radiation can promote skin cancer. Another physical factor of environmental pollution – noise – can cause discomfort, earache or hearing impairment; prolonged exposure can affect a person's mental health. Living organisms (biological environmental pollution) can also affect human health and ecosystems.

Figure 6.1. Laboratory animals are a common test object to evaluate toxicity of chemical substances

Consequently, an increasingly urgent need arises to assess the effects of substances and different factors on people who produce and use them as well as other living organisms and their communities – ecosystems, and to forecast their content in the natural environment in the future and to estimate their concentrations.

6.2. Effects of toxic substances on living organisms

The most important phases of substances' circulation once they enter the organism are:
- absorption;
- distribution of substances;
- biotransformation (metabolism);
- excretion.

Absorption, distribution, biotransformation and excretion are interconnected processes.

The probability of substance's absorption is influenced by:
- the mode of intake of the substance;
- concentration of substance;
- physical and chemical properties of the substance.

The effect of substances on a living organism depends on their transformation once they have entered the organism. The behaviour of chemical substances in ecosystems is influenced by migration of the substances in the soil, surface water, air and transfer in food chains.

The toxic effect of substances can manifest itself after the substances have come into the contact with an organism. The most likely way to ingest the toxic substances is with water or food through the digestive tract. However, the effect of substances that can be taken by inhalation or through the skin is also important. When inhaled, depending on their properties, the toxic substances enter the lungs and desorb from their surface (human's lung surface is 50-100 m^2), directly entering the circulatory system. In toxicology, the process, whereby a substance enters the organism is called absorption. For example, ingested or inhaled substances are considered to be outside the organism until they pass through cells in respiratory organs or gastrointestinal tract. Toxic impact on the living organism is exhibited only by absorbed substances, although a locally toxic effect, which can manifest itself, for example, as irritation, may take place before absorption of the substance.

Concentration of the substance in organism and the intake depends on the mode of consumption. In some cases, great amounts of substances cannot be absorbed, while in other cases even negligible amounts of a substance can be absorbed easily. For example, the intake of dichlorodiphenyltrichloroethane (DDT) through the skin is insignificant, however, even small amounts of DDT are effectively absorbed in gastrointestinal tract. When the substance enters an organism, it crosses various barriers – cell membranes, which must be penetrated both to enter the cell and to arrive at the next cell. Thereby only the substances which can effectively cross the cell membranes can be considered as toxic. The cell's metabolism processes proceed through particular segments in its membrane, which consists from proteins (Figure 6.2).

An important stage of toxic substances' intake is their transport through the membranes of cells. A special transport mechanism of substances is endocytosis. Through this mechanism, macromolecular substances and large particles can enter a cell. Endocytosis means that the substance is encompassed by a fragment of cell's membrane (Figure 6.3). The encircled substance and the part of membrane subsequently separate from the membrane and gets inside of the cell where, for example, it may be destroyed. Endocytosis is a substantial process in case of lung and liver cells. This way, for instance, asbestos particles are absorbed into the lung cells.

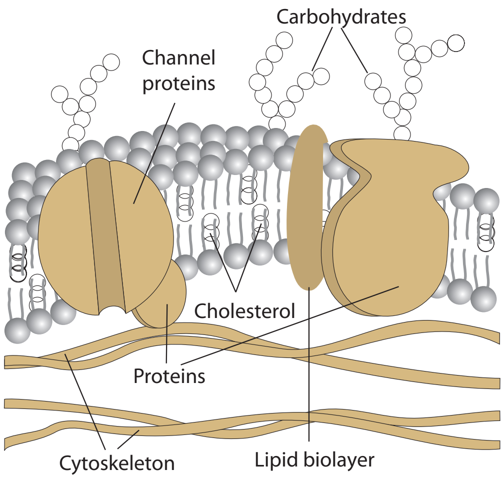


Figure 6.2. The structure of cell's membrane.

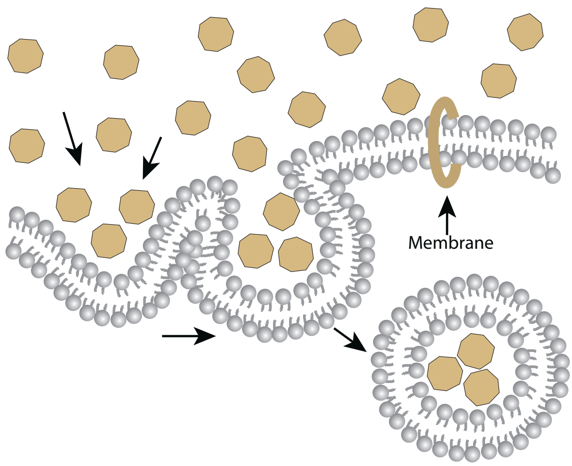


Figure 6.3. Entry of substances into the cell in case of endocytosis.

An important way of substance intake is through gastrointestinal tract. The environmental conditions change along the length of gastrointestinal tract rather significantly, first of all, the pH reaction. In the oral cavity the environmental reaction usually is close to neutral, in stomach it is pH ~2, but in intestinal canal it can be pH ~6. The large surface of intestinal canal and its connectedness with circulatory system ensures assimilation of substances in this segment of gastrointestinal system. The intake of toxic substances can also take place through skin, trachea, lungs, or, in case of aquatic animals, through the gills. In undamaged skin the main barrier to substance's entry into organism is epidermis. Since epidermis and other upper layers of skin are formed by lipophilic compounds, in most cases only lipophilic substances can diffuse through the skin. Water-repellent insecticides, for example, parathion can diffuse through skin and it has been proved that they may cause poisoning of people working with these substances. Even small molecules, for example, hydrazine may cause poisoning when taken through the skin. Ingestion of substances through lungs is particularly important to terrestrial animals, as it is the main pathway for the impact of atmospheric toxicants in form of gas or aerosol. The surface of human lungs is as large as 50-100 m^2 and an intensive gas exchange takes place there. At the same time, the barrier between the circulatory system and the air in alveoli can be only a few layers of cells. Therefore it can be considered that the absorption of substances through inhaling is fast and effective. Gases that dissolve well in the water, as a rule, sorb in the upper part of respiratory tract, interacting with water in the mucous membranes. The substances that dissolve in lipids, in gaseous (vapour) form (for example, chloroform) or small molecules (for example, carbon monoxide) in most cases reach alveoli, where they desorb and directly enter blood. Sorption of aerosol particles depends on their dimensions. If coarser aerosols (<20 µm) mostly are detained in the upper part of respiratory tract, the smaller aerosols (>10 µm) can penetrate the alveoli and from there they are eliminated very slowly. The aerosol particles whose size is less than 1 µm can be assimilated as a result of endocytosis, and be detained in respiratory system for a long time. Especially small aerosol particles can get directly in circulatory system. It has been proven that uranium dioxide particles (<3 µm) or lead aerosols after inhalation can enter the circulatory system.

When substances enter the organism, a number of different reactions take place with them, which generally are defined as metabolism, which consists of two parts: the catabolism and anabolism.

Anabolism (assimilation) – formation of new substances from low molecular weight compounds.

Catabolism (dissimilation) – degradation of organic substances and the release of energy

After the substances have adsorbed, they enter into the general circulation system of a bodys. After the absorption of substances, their distribution in the organism takes place. After crossing the «barriers» of the organism (skin, lungs or gastrointestinal tract) the substances enter the intercellular fluid, which encompasses the cells and comprises about 15% of the total body weight. Other body fluids are the cytoplasm, representing about 40%, and blood plasma – about 8% of the weight. From the intercellular fluid the substances can enter the tissues, blood capillaries and the circulatory system, as well as the lymphatic system. Substances, which enter the circulatory system, are quickly dispersed in the organism, unlike the lymphatic system, in which the speed of movement is significantly slower.

Metabolism (metabolic) products are called metabolites. Catabolism is the splitting of larger molecules, mainly as a result of hydrolysis and oxidation reactions, through the release and accumulation of energy. Anabolism is the synthesis of molecules specific to organism from low molecular weight fragments, and during this process the energy is being used. The degradation processes of xenobiotics are mainly associated with catabolic processes. At the same time the degradation of xenobiotics takes place according to the same principles as the metabolism of nutrients and other naturally consumed substances. The transformations of toxic substances can lead to formation of metabolites both with a lower toxicity (detoxification) and a higher toxicity (bioactivation).

As a result of the metabolic transformation the substances with a wide variety of origins, properties and structure are modified so that they can be eliminated or accumulated. The discharge of the toxic substances from the body affects the nature of their effect, since, if the excretion takes place quickly, even at the high toxicity of substance the hazard of exposure can be significantly reduced. The substance excretion speed from the body is described as either the elimination half-life time $\tau 1/2$. Substance elimination half-life from the body is the time at which half of the substance amount absorbed by the organism is being excreted from it.

An interesting feature of the toxic substances' detoxification system is that, if it is exposed to an influence of a small amount of toxic substance over a long period, the system can be induced, respectively – its ability to transform a particular substance may increase, thereby lowering the overall hazards of that particular toxic substance. However, on the other hand, there is also the possibility that if the system is induced to a non-toxic substance, a living organism can become more sensitive to the effects of other substances.

As a result of metabolism, the toxicity of xenobiotics and adverse effects on a living organism usually decrease, but relatively many cases are known when precisely the metabolic transformation of the substances that have entered the organism increases their toxicity. Often, particularly the biological activity of the primary metabolites may be higher than that of the initial substance. Transformation of many carcinogens (benzo[a]pyrene, aflatoxin, vinyl chloride) resulting from the metabolic processes lead to the formation of metabolites with a reactivity, which are able to bind to DNA. In other words, it is the metabolic processes wherein relatively inert molecules turn into their metabolites with a reactivity that cause damage to the biomolecules comprising the cells.

The metabolism of toxic substances stipulates that the organism or its tissue sensitivity to the effects of the toxic substance decreases as a result of exposure to the repeated dose. Such a phenomenon is called tolerance.

The metabolism of the toxic substances significantly affects the nature of the organism's reaction if exposed to more than one substance at the same time.

Depending on the nature of the organism's reaction it is possible to distinguish between four types of exposure:

1. additive effect, in which case the total toxic effect is formed as the sum of each substance's exposure effect («1 + 1 = 2»);
2. synergistic effect, in which case the effect of the toxic substances is increased («1 + 1 > 2»);
3. potentiation, in which case a non-toxic substance increases the toxic substance's effect («1 + 0 > 1»);
4. antagonism, in which case the effect of the combination of substances is less toxic than the individual effect of each substance («1 + 1 < 2»).

Toxic substances in the body are localized, depending on their characteristics. Fat-soluble (lipophilic) substances first of all accumulate in adipose tissue. Examples of such substances are polyaromatic hydrocarbons, polychlorinated biphenyls, phenyl-and methyl-mercury, DDT. Since these substances usually are also quite stable, such depositing is particularly dangerous to a living organism.

An important role in binding the toxic substances is played by proteins, the first to mention here is the blood serum albumin, which normally binds metabolic products such as fatty acids, bilirubin and hormones, ensuring their transportation. If a toxic substance is bound to albumin, it loses its ability to form complexes with natural metabolites, and this in itself can lead to toxic effects. Of particular importance is the effect of toxic substances on the nucleic acids, since it is based on the mutagenic and carcinogenic effects of substances. Among the known carcinogens which affect the nucleic acids are such substances as polycyclic hydrocarbons, polycyclic amines, aminoazobenzene, nitrosamines, aliphatic alkylating agents.

Accumulation of substances in living organisms can take place directly from air, soil or water, however, a significant proportion (depending on the nature of the substance and the place of the respective living organism in the food chain) can be taken with food. When substance is released into the environment, it is subjected to the impact of various factors, that leads to a possibility of quick and significant decrease of the substance's content. However, there are many substances, whose stability against biological degradation is high. Among such substances one must mention DDT, all chlorinated organic compounds, metals, and toxic microelements, organometallic compounds, radioactive elements.

The sustained high resistance of toxic substances to the influence of various environmental factors can be explained with their bioconcentration. Its measure is the bioconcentration factor (BCF). BCF is the ratio between the concentration of a substance in the organism and in the environment (water, soil). Bioconcentration ability of a substance is considered to be low, if BCF < 500, to be average high, if BCF ≈ 500-1000, but high if BCF > 1000.

$BCF = C_{organism}/C_{environment}$

For example, many sea birds that prey on fish are very effective bioconcentrators of toxic substances (Figure 6.4). Today, these bird species therefore are gravely exposed to pollution. Physiologically, it may take the form of bird sterilization and bird eggshell thinning.

For example, the ability of algae *Fucus* or *Laminaria* to bioconcentrate iodine from sea water allows them to be used for industrial extraction of iodine. Bioconcentration is the process by which the organism absorbs the substances necessary for its existence (trace elements, vitamins, fatty acids) from the environment.

Bioconcentration factor can also be expressed as the ratio between the speed of intake of a substance and its elimination speed from the body. In other words, the speed of metabolism or the speed of specific metabolic processes may greatly influence the character of substances' accumulation. At the same time the bioconcentration phenomenon is typical for substances that are not hydrophobic, in case if particular systems of organism are capable to assimilate the respective element in increased quantities. Particular research has

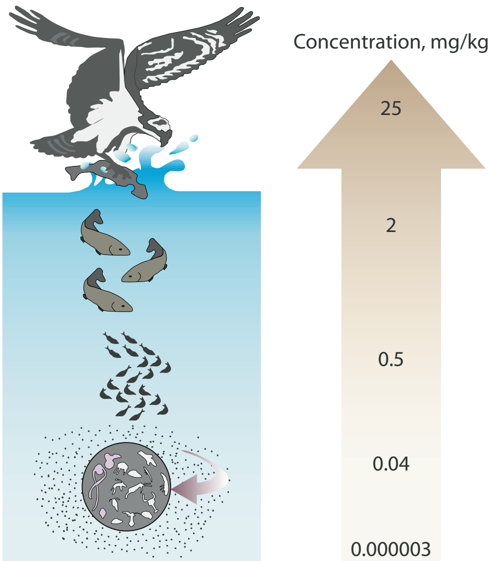


Figure 6.4. Bioconcentration of DDT in aquatic food chain

been devoted to the bioconcentration of organochlorine compounds. At the first trophic level a role of bioconcentrator may be assigned to phytoplankton and plants, especially if they are either rich in lipids (nuts, especially peanuts) or carotenoids, terpenes. Of particular importance is the ability of phytoplankton to concentrate, for example, organochlorine compounds. Accordingly, in the higher trophic levels the bioconcentration effect is determined not only by the consideration that the food base consists of the primary producers, but also by the fact that, once the living organism becomes more complex, the organs appear, in which toxicants can be deposited easier. Of aquatic animals, the molluscs should be mentioned first of all. It should be noted that the fish may ingest quite large quantities of toxic substances through the skin directly from the water.

Figure 6.5. Eagles are especially susceptible in respect to presence of pollutants in their food

An important factor that determines the degree of bioconcentration is the length of the food chain, which in case of aquatic living organisms is, on average, longer than for those living on the land. The DDT transfer and bioconcentration takes place similarly. Pesticides' bio-concentration in the terrestrial food chains is less pronounced.

All these facts prove that pollutants' dissipation process, as a result of which they enter the environment, can be considered as rather conditional. Since pollutants can concentrate at higher stages of the food chain, which also include the man, it is possible to create an inverted «pyramid of bioconcentration», by analogy with the «trophic pyramid».

6.2. Toxicity assesment of substances

Figure 6.6. Paracelsus 1493-1541. Paracelsus stated that the plant or animal venoms toxicity is determined by specific chemicals. He first described the correlations between dose levels and the body's response to them and showed that small doses of substances can be harmless or even beneficial, while high doses of the poisonous.

The effect of any substance or factor on living organisms depends on the nature of this effect (toxicity) as well as on the quantities of substances that enter the body. Most substances are harmless if the dose affecting the organism is sufficiently low, whereas even any well-known and widely used domestic substance in high doses may become hazardous to the human organism. Any effect on living organisms is dependent not only on the nature of the exposure, but also the amount of a substance that enters the body.

Any substance is harmless if their amount enters body in minimal amounts, but, but any in everyday life well-known and widely used substance in large doses becomes dangerous. The first this concept demonstrated Paracelsus (Fig. 6.6). His well-known statement «All substances are poisons; there is none that is not a poison. The right dose differentiates a poison and a remedy» is a bsic for dose-response relationship.

The amount of substance that a living organism takes in over a given period of time is called the dose.

The assessment of the hazardousness of a substance and risk of its exposure is based on the correlation between the dose of the substance and the body's response. The study of this correlation allows to evaluate the toxicity of a substance, for the toxic reaction usually depends on both the dose of the substance under study and the concentration of the substance in the part of the body affected first. Usually exposure to a substance is toxic if there is an interaction between the compound and a certain receptor in the body. The receptor might be an enzyme whose activity is inhibited. The binding to the receptor can be both reversible and irreversible; hence, the duration of exposure to the toxic substance is crucial. Although the concentration of the substance in tissue is directly proportional to the dose of the compound, several factors may influence the amount of the substance that actually brings about the toxic effect. The absorption of the substance, its distribution in the body, metabolic processes and discharge mechanisms can affect its concentration when molecules reach the receptor.

In order to assess the body's reaction to the amount of the substance taken in, other factors and conditions should also be taken into account. The key factors affecting the action of the substance are the number of doses, the nature of intake (continuous, in specific doses), the frequency of intake and the total time of action. Breakdown of the amount of the substance into separate doses, as a rule, reduces the toxicity of its action because the substance is transformed or eliminated from the body as a result of metabolism.

Curves in Figure 6.7. show reactions in the body depending on the quantity (dose) of the substance taken in.

Several types of doses are distinguished:

- contact dose – the amount of a substance taken in from the environment;
- absorbed dose – the actual amount of a substance that enters the body;
- total dose – the sum total of separate doses.

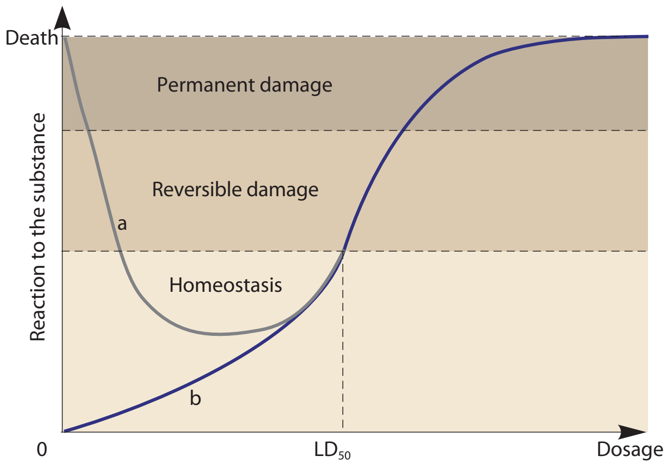


Figure 6.7. Reactions in living organisms depending on the quantity of the substance taken in:
a) the substance is necessary for the functioning of the body;
b) the substance is not necessary for the body

The effect of a substance on a living organism depends on the properties of the substance, the age and sex of the organism affected by the substance, the duration of action and recurrence of dose, the way the substance enters the body and the transformation of the substance in the environment and the body. For example, the effect of such a toxic substance as dioxin on different organisms varies greatly, and the nature of its toxic action depends on the sex of the organism used for testing purposes.

Table 6.1. Dioxin toxicity for various living organisms

Test organisms	*LD_{50} (µg / kg body weight)*
Guinea pig	0.6
Rat (female)	22
Rat (male)	45
Rabbit	115
Dog	30-300
Man (calculated)	>100
Hamster	1160

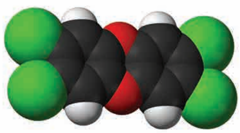


Figure 6.8. 2,3,7,8-TCDD (dioxin) – One of the most toxic substances known to be formed as a by-product of a number of organic synthesis processes, burning of organic materials.

The effects of a substance can vary within quite a broad range in one substance test group (population) – some individuals may have a high resistance against the effects of the substance, whereas this resistance may be low in other individuals.

The understanding of the effects of substances is based on the study of the reactions of living organisms in response to changing doses or concentrations of the substances studied. At the same time, the toxicity of a substance is considered to be one of its properties determined by its molecular structure (a property similar to the substance's molecular weight, volatility or the capacity to adsorb on solid surfaces). Consequently, the study of correlations between the toxicity of the substance and its composition can also be used for toxicity assessment.

The toxic effects are caused by the presence of a substance in the body. It can be taken in at one time, or its effects may add up. In the latter case, it may be necessary to assess the doses that can be taken in over a longer period of time. The simplest criterion of toxicity evaluation is mortality (lethality) although this indicator provides little information about the processes that determine the toxic effects.

One of the most widely used methods for toxicity assessment consists of the determination of the lethal dose of a toxic substance. Lethal dose (LD) is the amount of a substance that causes the organism's death.

The dose that causes death in a fixed part (usually 50%) of an animal testing group following the contact with the analysed substance over a given period (usually 24, 48 or 96 hours) is denoted as LD_{50}. Lethal dose is expressed in milligrams per kilogram of live weight (mg/kg). For toxic substances, LD_{50} is usually less than 15 mg/kg (Table 6.2). The LD_{50} value may vary depending on the duration of the action and the nature of the population.

Table 6.2. LD_{50} value for some substances

Substance	*Testing animal*	*LD_{50} (mg/kg of body mass)*
Ethanol	Mice	10 000
Sodium chloride	Mice	4000
Morphine sulphate	Rats	900
Phenobarbital	Rats	150
DDT	Rats	100
Strychnine sulphate	Rats	2
Nicotine	Rats	1
Tetrodotoxin	Mice	0.1
Dioxin	Rats	0.001
Botulinus toxin	Rats	0.0001

Acute toxicity can be defined as the total negative effect caused by a toxic substance taken in a single dose. Analogous to acute toxicity, chronic toxicity can be defined as the total negative effect caused by a toxic substance affecting a living organism over a longer period of time.

The effects of physical or biological factors can be assessed and studied like the effects of toxic substances, i.e. analysing the correlations between the doses (action intensity and amount) and the organism's responses.

6.3. Effects of pollutants and physical factors on humans and ecosystems

6.3.1. Types of toxic effects

Depending on the type of damage caused to organisms, the effects of toxic substances can be categorised as follows:
- direct toxic effects: tissue damage;
- changes in biochemical reactions;
- neurotoxic effects;
- immunotoxic effects;
- mutagenic effects;
- genotoxic effects;
- carcinogenic effects;
- effects on the endocrine regulation processes.

Although the changes that can be caused by the action of a toxic substance vary, it is possible to highlight some of the prevailing forms of toxicity.

The normal functioning of a human body is closely related to the environment. The prerequisites for life are twofold: a continuous exchange of substances, energy and information between the organism and the environment and the organism's ability to distance itself from the environment to such an extent that the changes in environmental physical and chemical parameters cannot significantly affect the basic life processes.

Any living organism (including a human being) is an indivisible unity of cells, tissues and organs.

Regulatory mechanisms provide for the functional unity of various tissues and organs, and specific defence mechanisms are responsible for the organism's relative independence from the effects of various external environmental factors:

- homeostasis – the organism's ability to maintain the internal environment and various bodily functions in a stable state in the changing internal and external environmental conditions. Homeostasis is regulated by the complex self-regulatory mechanisms of the organism;
- adaptation – the ability of living organisms to adapt to changing circumstances of existence developed in the evolutionary process. The organism's adaptation processes comprise various systems of organs, but the regulatory mechanisms of the nervous and hormonal systems are the most significant.

Although several stages can be distinguished within the adaptation process, when the environmental conditions drastically change, bodily function disorders followed by complex adaptation reactions mostly occur first. The organism is actively looking for a suitable state to meet the new circumstances. After that (in a favourable situation), the functions stabilise because the adaptation has taken place.

If foreign chemical substances enter the body, the adaptation process reinforces the activity of enzymes – they transform and destroy the chemical substances.

If the effects of environmental factors exceed the organism's adaptive capacity, it is broken down, initiating the exhaustion phase in which compensatory mechanisms start their action against the onset and progression of a pathological process. The effects of adverse environmental factors and pollution depend mainly on the organism's health condition, age and sex. Children and elderly people are much more sensitive to the harmful effects of pollutants than adults. This also applies to pregnant women and their unborn children, sick people and people with different pathological conditions, such as nutritional deficiency diseases and avitaminosis.

To fight the effects of adverse environmental factors, the body has developed several defence systems that ensure its ability to resist these adverse impacts. The skin and mucous membranes, the organs located on the boundary between the environment and organism (respiratory and digestive systems, the lymphatic system and urinary tract) as well as the immune system, mononuclear phagocytic system and defence reflexes perform the barrier function.

The purpose of immunoprotection is the organism's defence against genetically foreign cells and substances. The lymphatic tissue and organ systems perform the organism's immunoprotection.

The defence functions of the respiratory system are as follows: ciliary movement in the bronchial epithelium and excretion of mucus from the bronchial glands, bronchial muscle contractions, activity of the pulmonary macrophage system, secretion of immunoglobulins from the airway mucosa and stability in the pulmonary alveoli provided by a complex system of self-regulating surfactants.

In the process of evolution, the organism's defence system has effectively developed to combat naturally toxic substances and other adverse factors. However, the environmental pollution also contaminates the internal environment of the human body. Dust accumulates in the lungs, metal compounds are deposited in the bones, soft tissues and organs. Contamination in the human body initiates changes in the physical and chemical parameters of the organism's internal environment. A considerable contamination of the environment and organism can disturb the functioning of the organism's defence system.

If the harmful environmental conditions are excessively hazardous or persist for longer periods of time, exceeding the organism's adaptability, they become the risk factors for a variety of pathological conditions, illnesses or even death.

6.3.2. Effects of environmental pollutants and factors on human beings

Pollutant chemicals and biological factors (living organisms) might be present in the air, water, soil and food, and they can enter the body through the respiratory tract, gastrointestinal tract, skin, eye conjunctiva and placenta. The ways of entry depend on the aggregative state of substances and physical and chemical properties of compounds. Whatever the mode of absorption, all chemical substances enter the bloodstream and, from there, into various organs and tissues.

Bacteriologically contaminated water is the main cause of the diseases of the digestive system, skin, eyes and many other. Approximately 80% of diseases recorded on a global scale and more than a third of death occurrences in developing countries are directly related to the use of contaminated water.

The most representative physical pollutants of the environment are noise, vibration, non-ionising and ionising electromagnetic radiation.

The action of pollutants mostly affects those organs and systems that perform the barrier functions on the boundary between the environment and organism, preserving the organism's internal environment uncontaminated.

Diseases can develop from the effects of pollutants due to human susceptibility. Although the pathogenic effect always depends on the intensity and duration of exposure, persons who are more susceptible to diseases may fall ill even after a minor contact with a hazardous factor. Susceptibility depends on the biological factors (age, sex, heredity, other diseases), lifestyle (dietary regime, smoking, alcohol, stress), change of the environment if it was different in the previous place of residence or work.

Differences in susceptibility decrease with increasing exposure – in extremely hazardous conditions, both more susceptible and less susceptible persons may become ill. Children and the elderly are more sensitive to environmental pollutants.

6.3.3. Effects of environmental pollutants on the endocrine system

The endocrine system is composed of internal secretion glands, regulating many body functions through the hormones synthesised in these glands (Figure 6.9). Female organisms produce estrogenic hormones, whereas male organisms – androgenic hormones. The endocrine glands of the human body are the thyroid gland, parathyroid glands, the thymus, gonads, the adrenal gland and pancreas. The placenta, kidneys, the liver, fat tissue and the endothelium also have endocrine secretion functions.

Hormones are specific substances that are synthesised in different tissue cells (endocrine gland cells) and released from there into the intercellular solution, spreading through (or with) this solution and regulating target cell functions and processes throughout the body.

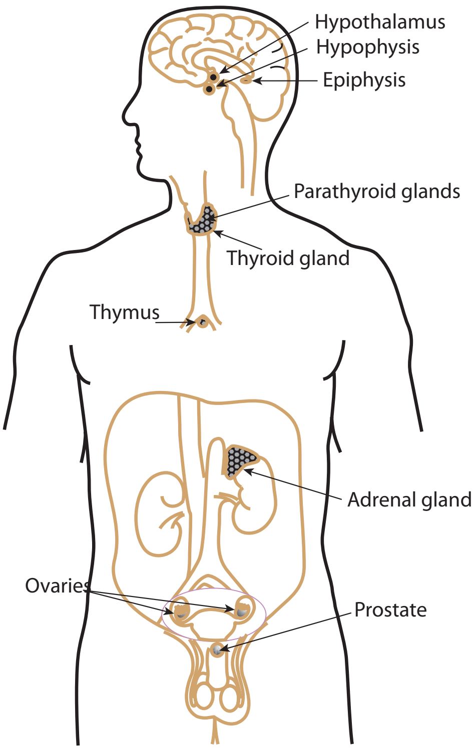


Figure 6.9. Hormone-producing glands in the human body

Hormones regulate the body's development and growth; they influence behaviour, regulate the reproductive cycle (the menstrual cycle, onset and progress of pregnancy) and significantly affect the functioning of the body (the functioning of skeletal, circulatory and immune systems as well as brain performance). Typical examples of reproductive hormones are estradiol, estrone and estriol.

There also are many substances whose structure and properties are similar to those substances that may actively affect the functioning of the endocrine system. Such substances may affect organisms in embryonic or foetal development stages as well as the reproductive system, central nervous system, immune system and endocrine regulatory processes. A typical characteristic feature of such substances is that their effects are initiated by low concentrations and may become manifest only in future generations. Just as carcinogenic substances, the substances affecting the endocrine system do not belong to one particular group of substances; the effects come about as a result of the action of various structurally different substances.

The most widely studied group of substances affecting the endocrine system are environmental estrogens or exoestrogens.

Usually, the intensity of natural reproductive hormone action is significantly higher than that of environmental estrogen (except for diethylstilbestrol and contraceptives). It has been proved that many structurally different substances have the capacity to affect the endocrine system. Environmental estrogens typically have both synergistic and antagonistic effects.

Natural hormones are unstable and disintegrate within a period ranging from a few minutes up to several hours after the formation. Unlike naturally occurring substances, environmental estrogens are persistent and may even accumulate in living tissue.

The main difference between the hormones produced in human or animal organisms and the substances that degrade the endocrine system is their origin and possible ways of assimilation. Considering the extensive use of various exoestrogens, their high concentrations in the environment have been proven (Table 6.3). The high environmental concentration of substances that degrade the endocrine system is also attributable to their high persistence as a result of metabolic transformations and chemical and biological degradation processes. Many substances that degrade the endocrine system are quite volatile; therefore, they may be disseminated with air masses although usually they are spread by water. Examples of such substances are the pesticide DDT, a substance that is widely used in the production of polymers – bisphenol A, a synthetic estrogen diethylstilbestrol as well as a variety of substances of a natural origin (Table 6.3).

Environmental estrogens, acting on living organisms,
- simulate the action of estrogen synthesised in the body. The substances affecting the endocrine system are capable of producing effects similar to those caused by endogenous steroids.
- block, eliminate or modify the bonding of hormones with their receptors, thereby affecting the quantity of hormones and type of effect on the cell. Such substances are called anti-estrogens or anti-androgens;
- alter the rate of production or decay of naturally formed hormones;
- affect the structure of hormone receptors or their formation in the body.

Table 6.3. Substances with estrogenic activity and their typical concentrations in the environment

Substance	*Concentration*	*Environment*
Estrone	$(1.4\text{-}76) \times 10^{-9}$ g/l	Wastewater
Oestradiol	$(2.7\text{-}48) \times 10^{-9}$ g/l	Wastewater
Nonylphenol	$(0.15\text{-}2.8) \times 10^{-6}$ g/l	Wastewater
Pthalic acid esters	3.2×10^{-6} g/l	Gull eggs
Polychlorinated biphenyls (PCBs)	14.1×10^{-3} g/kg	Wastewater

Food may be considered to be the major source of intake of substances affecting the endocrine system: food products that contain these substances, food additives and food packaging.

Endocrine system regulation disorders, in turn, can affect the central nervous and immune system. These disorders may occur already in the embryonic development stage, and they can cause sexual behaviour changes, slowdown in the development of secondary sexual characteristics, prostate disorders, decrease in sperm production and sexual activity, reproductive function disorders, male feminisation, formation of malignant tumours.

Environmental estrogens are
- pesticides – the estrogenic activity of many pesticides has been proven (DDT, endosulphan, dieldrin, kepone, dicofol, toxaphene, chlordane, alachlor, atrazine, nitrophen, benomyl, mancozeb, aldicarb);
- substances used in manufacturing polymers (bisphenol A, phthalates);
- therapeutic substances (diethylstilboestrol, cimetidine);
- chemicals of domestic use (surfactant degradation products – nonylphenol and octylphenol);
- many environmental pollutants (polychlorinated biphenyls, dioxins, polyaromatic compounds);
- heavy metals and their compounds (lead, mercury, cadmium).

The thyroid gland is particularly susceptible to the adverse effects of environmental factors. Studies show that elevated concentrations of heavy metals – lead, manganese and mercury – in the environment cause pathological changes in the thyroid gland.

The proven effects of substances that affect the endocrine system manifest themselves in the form of reproductive system abnormalities and development delays. These effects have been proved by both laboratory studies and cases when these substances entered the environment, affecting the development of living organisms. It is believed that these substances contribute to malignant tumour development. For example, diethylstilboestrol was used as a medication to reduce premature birth risk, and a considerable increase in the cancer mortality rate in the daughters of women who used this medication was proven only much later. From the ecotoxicological point of view, the impact on wild animal populations has been acknowledged as particularly substantial. It is believed that the substances that have an effect on the endocrine system have affected, for example, the populations of fish and birds of prey in the Great Lakes Region, the population of alligators in Lake Apopka (Florida, the USA) and the population of otters in western Europe.

6.3.4. Genotoxic effects of environmental pollutants and factors

According to the mechanism of toxic effects, three groups of substances can be distinguished: mutagens, carcinogens and teratogens. Their effects are related to cell metabolism processes and impact the transmission of genetic information (Figure 6.10).

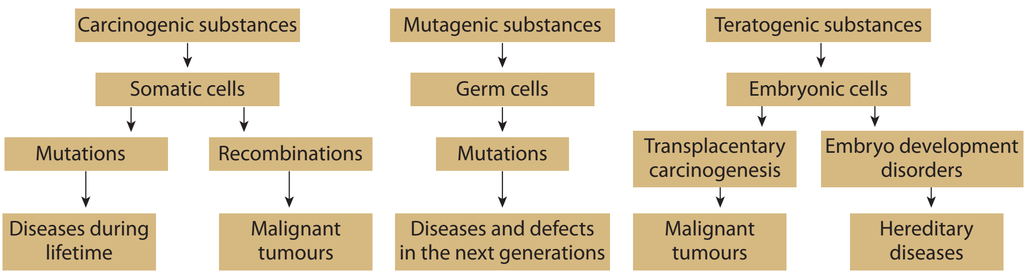


Figure 6.10. Effects of mutagenic, carcinogenic and teratogenic substances on living organisms

Mutagenic substances or factors cause mutations – heritable changes in the cell genotype. They can be chemical substances or physical factors, such as ionising radiation. Mutations that occur in generative cells are generative mutations, and they result in mutant organisms. Mutations in somatic cells occur in few body parts.

Mutations can also occur when a substance becomes 'trapped' between the chains of a DNA double helix. This situation may either destroy the conformation of the DNA double helix, or cause an erroneous reading of information from it.

6.3.5. Carcinogenic effects of environmental pollutants and factors

A major adverse effects of environmental pollutants is associated with their role in malignant tumour development. Malignant tumour is a generic term for more than 200 diseases characterised by uncontrolled cell division. Malignant tumours that develop in connective tissues are called sarcomas, whereas those that develop in epithelium tissue – cancers. Tumours develop not only in humans but also in animals and plants. Benign tumours grow slowly, moving the surrounding tissues. They are often encapsulated, do not form metastases and do not recur. Usually the forms of tumours are classified according to the location of the tumour in the body or certain organs, for example, the circulatory system cancer, lung cancer, brain cancer. Different forms of cancer have different causes. A range of cancer risk factors have been definitely proven, for instance, smoking, radioactive radiation, unhealthy diet. Heredity is considered one of the main risk factors. There are families that have a significantly higher risk of developing cancer than others. For example, a woman's risk of developing breast cancer increases from 1.5 to 3 times if her mother or sister had it. Sometimes breast cancer is associated with specific gene mutations, which are prevalent among certain ethnic groups or families. The possibility that women with such a gene mutation will develop breast cancer is significantly higher.

In addition, the effects of physical factors can cause cancer. These factors include ionising and ultraviolet radiation. Usually the physical factors cause specific forms of cancer; therefore, by reducing their harmful impact, it is possible to reduce significantly the spreading of certain forms of cancer. People working in certain professions can be exposed to ionising radiation, for example, operating X-ray equipment or nuclear reactors. Uranium mining workers have a very high risk of cancer; for those who smoke, the risk increases several times. The most common diseases caused by ionising radiation are lung and blood cancer. Lung cancer is caused by inhaled radioactive dust. This dust accumulates on the lung surface and, in long time, may cause a malignant transformation of cells. People who survived the Hiroshima and Nagasaki bombing were at considerably increased risk of developing leukaemia.

Humans are exposed to UV radiation while outdoors. Long and intensive UV radiation can cause skin cancer. The intensity

Factors that can cause cancer are:

- inherited susceptibility. It is believed that only 5% of cancer incidences in the USA are attributable to hereditary genetic mutations in the human genome. In early childhood genetic factors determine the development of cancer, but it is not the main cause of incidences;
- environmental carcinogens;
- inherited susceptibility heightened by the effects of substances that cause cancer. These factors are the main cause of cancer today, accounting for 60-90% of cases;
- unknown factors.

of radiation depends on the geographical location, climate and thickness of the layer of the stratosphere. The UV radiation exposure is increased in the countries with high proportion of clear days as well in the territories over which the ozone layer has been depleted. Exposure to substantial doses of UV radiation can also take place in specific industries and occupations, for example, colour coating and printing, medicine (sterilisation with UV lamps), welding.

Smoking and tobacco use are risk factors that have the second highest mortality rate. The incidence of lung cancer in smokers is 50-20 times higher than in non-smokers. The death rate related to lung cancer has been growing steadily since the beginning of the 20th century and is not expected to fall in the foreseeable future. Cigarette smoke contains around 4000 chemicals. There is evidence that many of them are carcinogenic. Smoking also significantly increases the incidence of mouth, larynx and bladder cancer.

Unhealthy eating habits also are a very important risk factor for cancer. People who are not on a proper and healthy diet are prone to the effects of carcinogenic substances. This risk may be reduced by means of a balanced diet and proper food preparation.

Several carcinogens significantly increase the risk of malignant tumour development by acting on cells, more precisely – directly on separate segments of the genome.

Of the various causes that affect the mortality rate from malignant tumours, food and smoking are the dominant ones, and substances that enter the body through smoking or are ingested with food are the main sources of carcinogenic effects (Figure 6.11).

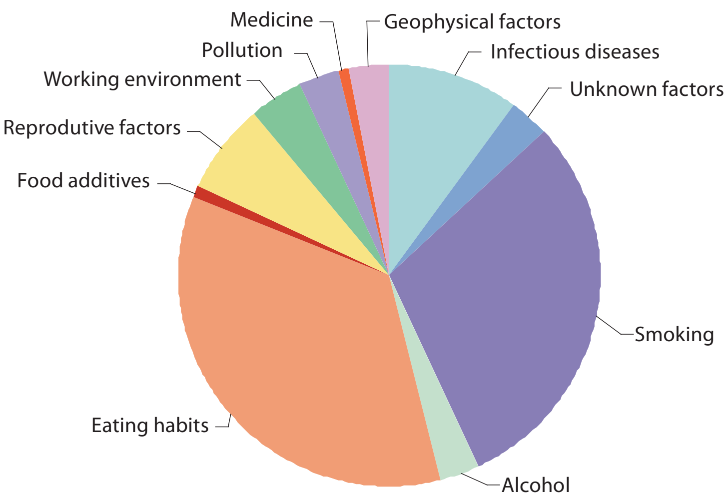


Figure 6.11. Effects of various causal factors on the mortality rate from malignant tumours

The development of malignant tumours is to a large extent determined not only by genetic factors and the predisposition of an organism but by the action of substances on particular elements of the human genome. Arguably, if the action of substances and factors that promote the development of cancer were prevented, the number of cancer occurrences would decrease, even though it is not easy to prove the effects of hazardous factors and substances because there is often a considerable time span between the action of a substance and tumour development.

The most common carcinogens are substances of anthropogenic origin, but also natural substances. Aflatoxins are an example of such a natural substance; they originate from moulds and contribute to liver cancer development.

However, when the cells stimulated in this way are not subject to mutation, they do not transform into cancerous cells.

Food and substances used for intoxication (e.g., alcohol, tobacco, drugs) can be a source of carcinogens. Tobacco smoke contains many carcinogens. Alcohol and foods with a high fat and low fibre content may also increase the risk of developing malignant tumours. Mould growing on protein-rich products (e.g., rice, peanuts) may contain aflatoxin. Contact with carcinogenic substances and factors such as benzene, tar products and radiation may take place at the work environment. Furthermore, viruses can be quite an important factor contributing to the development of cancer – for example, the Epstein-Barr virus, which belongs to the *Herpesviridae* family.

Malignant tumours can be caused by

- any substances or factors that cause DNA damage: chemicals (carcinogens), ionising radiation;
- substances, organisms or factors that stimulate cell division. For example, hormones that stimulate cell division, viruses (the papilloma virus, which is a risk factor for cervical cancer, hepatitis B and C viruses, which can facilitate cancer development in the liver, herpes viruses).

6.3.6. Teratogenic substances

Teratogenic substances affect the reproductive function of living organisms. These chemicals cause foetal (embryonic) defects. This phenomenon occurs both in humans and in animals and plants. From Greek, the words '*terat-, teras*' mean 'monster, monstrosity'.

Hereditary pathology studies have shown that it occurs in 2-3% of newborn children. 25% of the pathologies are genetically inherited, including mutagenic pathologies, 50-10% are caused by teratogenic effects, while the remaining 60-65% have unknown causes – most likely, it is a joint effect of both genetic and environmental factors. There are about 25 known chemicals that have teratogenic effects on humans and up to 800 – on animals. Many of the latter can also be potential human teratogens.

There are several risk periods in the development process of an embryo. For a human embryo such a period is the 18^{th} to the 55^{th} day of pregnancy, when the organs are developing (Figure 6.12). During this period, the embryo is especially sensitive to chemical factors. Contact with teratogens can reduce the size and number of cells, which can lead to the retardation of vital organs or foetal growth in general. In the 1960s, the sleeping pill thalidomide was the cause of incompletely formed limbs in neonates (e.g., a shorter arm or no arm at all). Mothers had been using this drug during the first months of pregnancy.

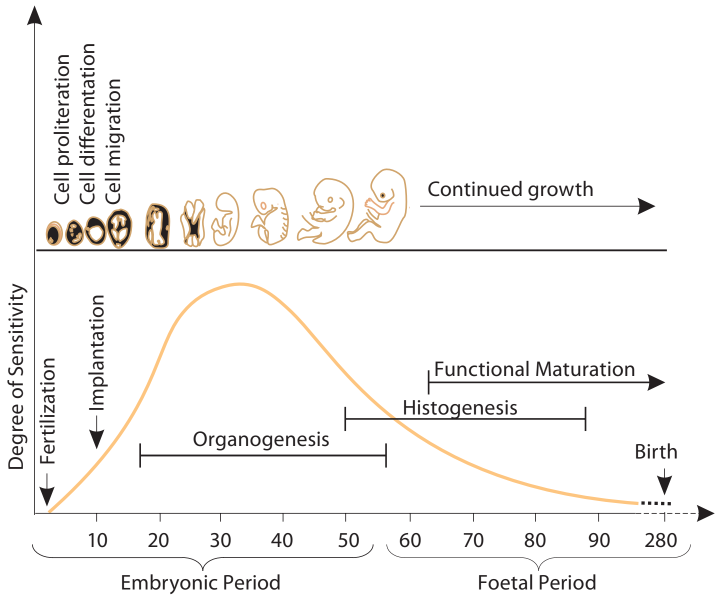


Figure 6.12. Main phases of the development of the human body

The effects of teratogens were also observed from large doses of vitamin D and the use of drugs for treating certain malignant tumours. Tests on animals have shown that even relatively common environmental pollutants, such as carbon monoxide CO (from car exhaust and smoking), have teratogenic effects. Carbon monoxide can diffuse through the placenta and increase the concentration of carboxymethyl-haemoglobin in the embryo's blood. Cadmium, lead and mercury are also teratogenic. The chemical mechanism of teratogenicity has not been fully researched yet. The most important groups of substances that have teratogenic effects are summarised in Table 6.4. Compounds of various classes can be teratogenic, but their common property is the capacity to diffuse through the placenta.

There is a close relationship between the substances with carcinogenic and mutagenic effects, whereas teratogens cannot be likened to any of these groups.

Table 6.4. Main substances with teratogenic effects

Substance	Effect
Metals and their compounds	
Lead	Facilitates spontaneous abortion and nervous system disorders
Methylmercury	Teratogenic effect on the nervous system
Lithium	Teratogenic effect on the heart
Aluminium	Teratogenic effect on the nervous system
Arsenic	Teratogenic effect
Pharmaceuticals	
Diethylstilbestrol	Adenocarcinoma
Thalidomide	Teratogenic effect
Retinoids	Teratogenic effect
Chemicals	
Ethyl alcohol	Intoxication of the foetus
Chloro-organic pesticides	Facilitate spontaneous abortion
Polychlorinated biphenyls	Teratogenic effect
Ethylene oxide	Facilitates spontaneous abortion
Dioxin	Teratogenic effect

References

Information notices on diagnosis of occupational diseases. (2009) Luxembourg: Office for Official Publications of the European Communities.

Investigating Environmental Disease Outbreaks: A Training Manual. (1991) Geneve: WHO.

Newman M. C. (1998) Fundamentals of Ecotoxicology. Ann Arbor Press.

Timbrell J. A. (2002) Introduction to Toxicology. 3rd ed. London: Taylor and Francis.

Walker C. H., Hopkin S. P., Sibly R. M., Peakall D. B. (2001) Principles of Ecotoxicology. 2nd ed. London: Taylor and Francis.

Wright D. A., Welbourn P. (2002) Environmental Toxicology. Cambridge: Cambridge University Press.

Aldridge W. N. (1996) Mechanisms and concepts in toxicology. Washington: Taylor and Francis.

Appraisal of tests to predict the environmental behaviour of chemicals. (1985) (Ed. P. Sheehan, F. Korte). Chichester: J. Wiley.

Aquatic ecotoxicology (1991) Fundamental concepts and methodologies (Ed. A. Boudon, F. Ribeyre), Boca Raton: CRC Press.

Gibaldi M. (1990) Biopharmaceuticals and clinical pharmacokinetics. Baltimore: Williams and Wilkins.

Handbook of environmental chemistry (Ed. O. Hutzinger) vol. 1-24 (1980–1994), Berlin: Springer Verlag.

Lu F. (1996) Basic Toxicology. Washington: Taylor and Francis.

Moriarty F. (1999) Ecotoxicology: the study of pollutants in ecosystems. London: Academic Press.

Timbrell J. A. (1996) Principles of biochemical toxicology. London: Taylor and Francis.

Timbrell J. (2002) Introduction to toxicology. Washington: Taylor and Francis.

Wexler P. (1998) Encyclopedia of Toxicology. N.Y.: Academic Press.

Walker C. H., Hopkin S. P., Sibly R. M., Peakall D. B. (2001) Principles of ecotoxicology. Washington: Taylor and Francis.

A Small Dose of. Accessible: *www.asmalldoseof.org/*.

Agency for Toxic Substances. Accessible: *www.atsdr.cdc.gov*.

European Centre for Ecotoxicology and Toxicology of Chemicals. Accessible: *www.ecetoc.org/*.

Hazard Database. Accessible: *www.evol.nw.ru/~spirov/hazard/*.

Information Toxicology International. Accessible: *www.infotox.com/*.

Pollution Information Site. Accessible: *www.scorecard.org/health-effects/*.

Toxicology Source. Accessible: *www.toxicologysource.com/*.

7. AIR POLLUTION

Protection of air from pollution is a matter of great importance. Air is one of the essential factors making life on the Earth possible. Atmospheric air is composed primarily of nitrogen (78%) and oxygen (21%). While the rest of the components' share of mass only about 1%, their role is significant. Environmental pollutants belong to the atmospheric trace constituents (Figure 7.1).

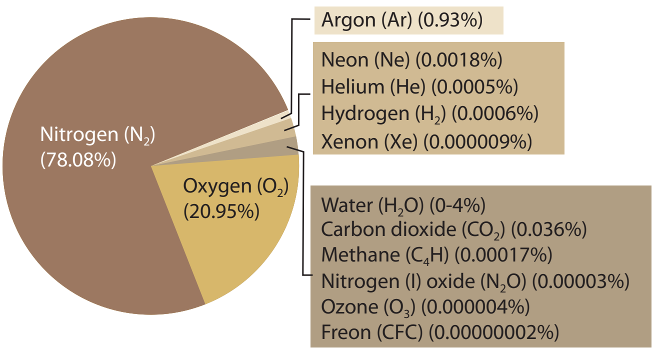


Figure 7.1. Composition of air

Depending on the body constitution, a human being consumes 6-13 m^3 of air daily or even more in cases of heavy physical loads. Consequently, trace amounts of harmful substances in the air may have an adverse effect on the human health.

Pollutants spread rapidly and to far distances in the atmosphere; therefore, the problem of atmospheric pollution should be dealt with on a global scale, and international cooperation is vital in this regard. Air cleanness in dwelling premises and working environment is a special air pollution problem because today people become increasingly exposed to hazardous and toxic substances at home or work. The air pollution problem has been accompanying us already since the times the ancient people discovered fire. From today's perspective, there is no doubt that the ancient people's health or even life were endangered by high concentrations of such pollutants as carbon monoxide (CO) released from incompletely burnt firewood and other compounds emitted during burning. Furthermore, the ancient Romans already knew about lead and mercury poisoning in mines.

Figure 7.2. Oil refinery plant (Italy). Crude oil, coal processing and petrochemical refinery plants are among the major sources of environmental air pollution.

Air pollution hazard has sharply increased since the development of Industrial Revolution and the mining industry. Industrial development in the last century came into view first of all with smoke tails from factory chimneys (Figure 7.2). Some production processes, for example soda production, entailed the release of a large number of aggressive and toxic substances into the environment. The first victims of air pollution were factory workers and people living near factories. In addition, many workers became industrial accident victims. Since labour safety was among the issues actively dealt with concurrently with other workers' social protection issues, a certain progress was achieved in this field in the course of time. Yet the overall industrial development and emission of hazardous substances reached such levels that labour protection at workplaces alone could not safeguard them against health damage. The London Great Smog caused by adverse weather conditions in 1952 lasted for several weeks and took its toll: about 4000 people had died prematurely and 100 000 more were made ill due to the smog's effects. Around this time, photochemical smog began to occur in the USA (Los Angeles) and Japan. In the 1970s the attention turned to precipitation pH changes, but at the beginning of the 1980s – to stratospheric ozone layer changes.

Although a range of air environmental protection measures are being implemented today, it is estimated that the losses incurred by the effects of polluted air on the human health – medical expenses, loss of working capacity – still amount to hundreds of millions of euros per year just in the European Union countries.

Industrial pollution mostly occurs in the industrially developed regions of North America, Europe and Asia. The main sources of anthropogenic pollution that also affect the quality of air are energy production, heating, transport, industrial production and agriculture, whereas the main air pollutants are

a) sulphur compounds;
b) nitrogen compounds;
c) carbon compounds;
d) halogenated organic substances;
e) metals and their compounds;
f) aerosols and dust;
g) radioactive elements.

Both industrial processes and heating contributes to air pollution. Incineration of household waste pollutes air significantly. From traditional fuels, coal is the most polluting. Another considerable pollution source group is motor transport – as motor exhaust gases contain various harmful substances. The exhaust gas composition may differ depending on driving habits, engine operating conditions, fuel supply and quality. In the process of incomplete combustion of fuel hydrocarbons, they are transformed into carcinogenic substances – polyaromatic hydrocarbons. According to the total emission amount of some pollutants, motor transport has become a major pollution source in today's cities.

Many production processes are characterised by the emission of specific pollutants. Nowadays countless very harmful substances are used in both industry and housekeeping, and they can enter the air of a work area or the atmosphere in the form of gas, vapour, aerosols or dust. To protect both workers and residents, several criteria (limit value) have been established in order to limit the maximum permissible concentrations of various harmful substances in the air.

Air quality measurements for air pollution analysis are usually made in ambient air. However, air pollution in the human living environment – dwelling premises and workplaces – may affect the human health considerably more. All kinds of local sources – such as kitchens, stoves, furniture, polymers, painted surfaces, domestic animals – can cause serious indoor air pollution. Room ventilation also affects the air pollution level. Ventilation should be balanced with the need to maintain the optimum temperature in dwelling premises.

Pollutants quickly spread over rather long distances in the atmosphere, therefore the solution to atmospheric air pollution problem should be considered internationally. A specific air pollution problem to be addressed is air quality in residential areas and working environment. These issues relate to the fact that humans are increasingly faced with harmful and toxic substances both at home and at workplace.

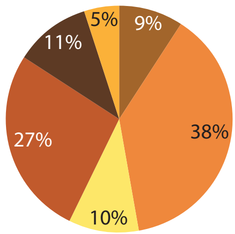


Figure 7.3. Emissions of pollutants from stationary pollution sources in Uzbekistan

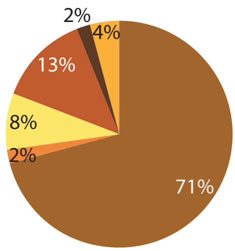


Figure 7.4. Emissions of pollutants from mobile pollution sources in Uzbekistan

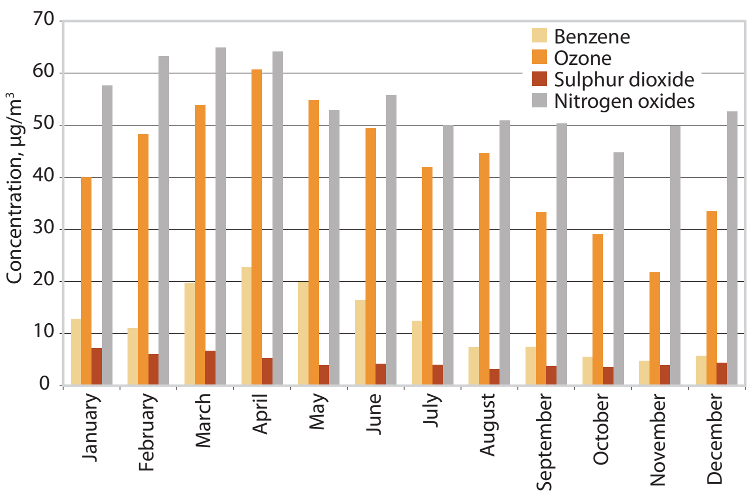


Figure 7.5. Average monthly pollutant concentrations in Riga air

The harmful effects of lead and mercury deposits were observed already in ancient Rome. The negative influence of soot and dust resulting from burning coal exposure was noted already in medieval London. As early as in 1273 the King of England Edward the First passed a law aimed at limiting air pollution resulting from the burning of coal.

In 1661, John Evelyn described the London air: «It is a dirty and thick fog with a terrible smell that leaves people with a thousand troubles and poisons not only the lungs, but also the entire body, so that in this city the pulmonary catarrh, cough and dizziness spreads increasingly.»

Figure 7.6. Smog in Beijing, 2003

The discovery of fire led ancient man to be confronted with air pollution. From today's perspective there is no doubt that the ancient humans' health and even lives were threatened by such pollutants in the air as high carbon monoxide (CO) content that could be released both as a result of the variety of geothermal processes, and as incomplete combustion of fuel. Along with the development of livestock breeding, the elevated ammonia and amine content in the facilities where the animals were kept became a certain factor of danger. A drastic increase in air pollution hazards was caused by the development of the early production and mining processes.

The high-tech industry in the 20^{th} century was marked first of all by the factory chimney smoke «tails». However, some manufacturing processes, such as soda production, were associated with release of a large amount of highly aggressive and toxic substances into the environment. The first air pollution victims were the people working in their respective factories as well as the people living nearby. Industrial accidents, too, claimed their share of victims. Thus, a few thousand people suffered and about 60 people died of the industrial air pollution in Meuse Valley (Belgium), in 1930. In 1984, in Bhopal (India), as a result of poisonous substance – methyl isocyanate – escaping into air, about 20 000 people died. Since occupational health and safety was one of the issues actively addressed alongside other social protection issues of the workers, with time a certain progress in this area was achieved. However, the overall development of production reached such levels that the protection of workforce could not provide safety for a person in his or her living environment, since emission of harmful substances had reached huge dimensions. In 1952, as a result of bad weather, smog enveloped London and lasted for several weeks. Around 4000 people suffered. A similar situation was registered in 1956. At this time, formation of photochemical smog in the U.S. (Los Angeles), and Japan was initially observed. Today, smog is observed in China (Figure 7.6), Mexico and other countries. In the seventies, the attention was drawn to changes in pH of precipitation – precipitation acidification problem. At the beginning of the 80s there came the awareness of the stratospheric ozone layer structure changes – the formation of an ozone hole.

In response to new environmental problems and growing of local pollution manifestations into global ones, methods were developed to overcome them, both as technological answers to particular problems and as solutions for public and industrial management (Figure 7.7).

Industrial and anthropogenic pollution predominantly occurs in North American, European and Asian industrially developed regions.

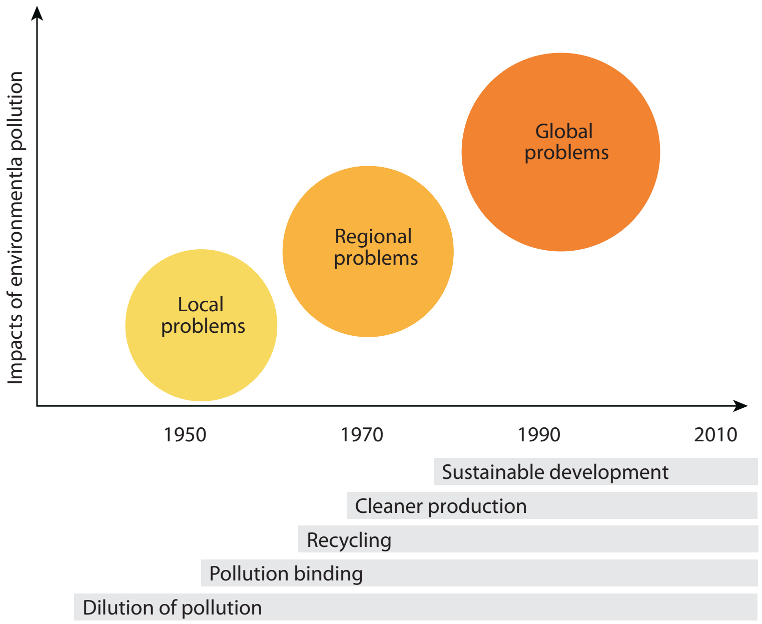


Figure 7.7. Environmental pollution problems and their solutions

Air pollution is generated both by the industrial processes and heating. Significant air pollution is caused by burning household waste. From traditional fuels, the most polluting is coal, which has a high bituminous matter and sulfur content. The design of a furnace, stove or a heating system is of great importance, respectively, optimal temperature and air supply must be provided for combustion of each fuel. Compared to the case of solid fuel, the combustion process is significantly easier optimized for gaseous and liquid fuels. In this case, the relevant matter is the presence of sulfur-containing compounds in the fuel.

Another major pollution source is transport. This is due to the fact that the engine exhaust gases contain a range of various harmful substances. From a practical point of view, it should be noted that the engine exhaust gas composition is highly dependent on driving and engine operating conditions, fuel supply and quality. When idling and driving at lower engine speeds, the exhaust gas contains a greater amount of carbon monoxide and hydrocarbons. In the process of incomplete combustion of gasoline, cracking of hydrocarbons and other transformations occur, leading to formation of polyaromatic hydrocarbons, which are generally known carcinogens. Modern transport in cities in terms of total emission amount of certain pollutants has become a major source of pollution.

Many production processes are characterized by emission of specific pollutants.

There are four main anthropogenic sources of pollution affecting the air quality:

1. power industry and heating;
2. transport;
3. industry;
4. agriculture.

Whereas the major air pollutants in the environment are:

1. sulfur compounds;
2. nitrogen compounds;
3. carbon compounds;
4. halogenated organic substances;
5. metals and their compounds;
6. aerosols and dust;
7. radioactive elements.

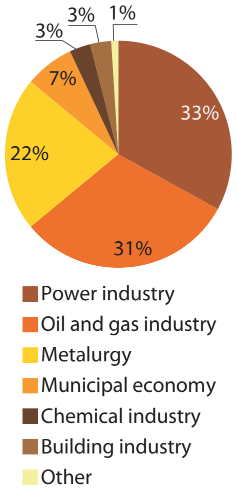


Figure 7.8. Contribution of industrial production in air pollution

Production intensification and general growth, various modes of transport, energy industry development and other factors combine to determine the quality of human life and the level of comfort. However, in this process, the natural environment that surrounds people becomes increasingly polluted, and at a certain stage of development can become harmful to humans themselves. The main mechanisms for control of environmental pollution are legislative and economic levers, as well as introduction of eco-friendly manufacturing processes.

When creating the environment protection mechanism, one should take into account not only its task of protecting the people and the natural environment, but also the obvious need to promote and develop the respective production and technological processes. It is a fact that at the current stage of scientific and technical development technical implementation of the nature conservation measures may turn out to be so costly that the respective industry can become economically unfeasible.

There have been many negative effects caused by air pollution, especially an increased risk of developing heart and lung disease, as well as the reduction of life span by a year or more for those people who reside in contaminated areas. Some of these effects can be observed at very low concentrations – much lower than those initially considered safe.

Air pollution can lead to a great variety of diseases, from simple and transient changes in the respiratory tract or lung function deterioration, to the physical activity constraints, chronic conditions, hospitalisation and even death. Furthermore, the impact of air pollution is detected not only on the respiratory system, but also on the cardiovascular system. Air pollution can affect life expectancy and its decrease can be caused both by long-term exposure to polluted air, by being subjected to high pollutants' concentration even for a short period of time.

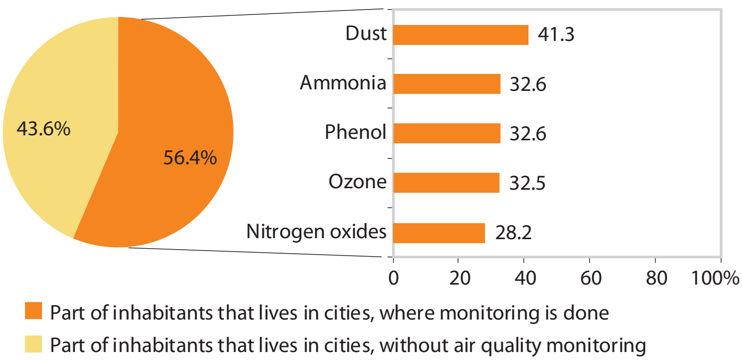


Figure 7.9. Urban population in Uzbekistan living in areas where concentrations of air pollutants regularly exceed of maximally permissible concentrations

There are several groups of people that are potentially more sensitive to air pollution than others. Particularly sensitive to air pollution are infants and young children as well as older people and those suffering from cardiovascular diseases. Healthy people are less susceptible than those who already suffer from respiratory diseases (asthma, chronic bronchitis).

Today, the industry and households generally use a large number of harmful substances, which in the work process can spread either in the surrounding area or atmospheric air in the form of gas, vapour, aerosol or dust. In order to protect the workforce and the population, there is a whole range of criteria (concentration limits), restricting the maximum permissible concentrations of various harmful substances in the air (Table 7.1).

Table 7.1. Air quality standards for major air environment pollutants

Pollutant	*Concentration of substance in the air analysis' duration*	*U.S.A. air quality limits*	*EU air quality guidelines*
Carbon monoxide (CO)	8-hour average	10 mg/m³	10 mg/m³
	1-hour average	40 mg/m³	-
Nitrogen dioxide (NO_2)	the average annual	100 µg/m³	40 µg/m³
	1-hour average	-	200 µg/m³
Ozone (O_3)	8-hour average	157 µg/m³	120 µg/m³
	1-hour average	235 µg/m³	-
Sulfur dioxide (SO_2)	the average annual	78 µg/m³	-
	24-hour average	365 µg/m³	125 µg/m³
	1 – hour average	-	350 µg/m³

Air pollutants directly affect human health, attacking respiratory organs, irritating eyes and mucous membrane, affecting blood components, and generally acting as toxic substances.

The impact of some harmful substances may become apparent immediately: this is the case, if such substances as phosgene or chlorine have a direct effect on the respiratory tract. If the harmful substances enter the human body in small quantities, and subsequently are spread throughout the body with the blood or lymph, they usually accumulate in a single organ, such as kidneys, liver or bones, and the harmful effects may occur after a latent period, which may be rather long.

Air pollution affects plants significantly more than animals and humans. It is, first of all, due to the fact that the animal respiratory process is based on use of oxygen, whose content in the air comprises 21%, but the green plants assimilate the carbon dioxide, which is available in significantly lower concentration (0.03%). Thus, the plants come in contact with larger quantities of pollutants found in the air. At the same time, normal growth and development of plants depend on a host of other factors (water, light regime, micronutrient balance), which may encumber an accurate impact assessment of the harmful substance.

In the analysis of air pollution, the air quality outdoors is usually examined. At the same time, people's health can be affected significantly more by air pollution in the living environment – home and working environment. This is determined by several factors, including the air pollution of human living environment, caused by an external air supply. An example of such a situation can be the heightened lead and polyaromatic hydrocarbon content in the dwelling houses near highways. Serious indoor air pollution can be caused by a variety of local sources – kitchens, ovens and furniture, polymer materials, painted surfaces, pets. The level of environmental pollution with any substances is also affected by the ventilation, its intensity must be balanced against the need to maintain an optimum indoor temperature regime.

Another factor that affects the indoor air quality is manufacturing of new materials and substances, which results in new pollutants entering the human living environment in increased quantities, and thereby contaminating it. For example, new insulation materials, cleaning products, cosmetics formulations, solvents, plant protection products cause human contact with chemicals that can be toxic. The pollution of the environment can cause a variety of effects, including immediate death. Many people have perished from poisoning by carbon monoxide gas coming from stoves and fireplaces. Even in developed countries, indoor pollution may be lethal, as evidenced by the deaths caused by indoor air contamination.

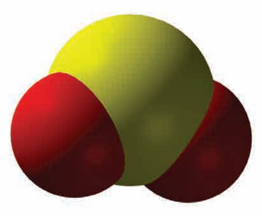


Figure 7.10. Formula of sulphur dioxide

7.1. Sulfur compounds in the atmosphere

The most significant source of sulfur and nitrogen compounds in the atmosphere today is economic activity. In 2006, 65% of the total sulfur compounds in the atmosphere were released as a result of human activities, furthermore, 90% of that amount accounted for sulfur dioxide.

Sulphur is a widespread element on the Earth: its average concentration is 1.8 to 2.9%, but in the atmosphere just 0.6 $\mu g/m^3$. Most of the sulfur compounds are found in the lithosphere and hydrosphere. The occurrence of sulfur compounds in the environment has increased significantly with intensified human economic activities and, first of all, it must be associated with the start of the

Industrial Revolution. The sulfur compounds have been extracted from the lithosphere in such processes as mining of ores (many metals are in the form of sulfide and sulfate ores), fuels (coal, oil, peat) burning and fertilizer production.

Natural sulfur compound sources are evaporation from water reservoirs (potassium, sodium sulphate-containing aerosols are formed), volcanic activity, forest fires. As a result of natural sulfur emission from biological sources the most widespread substances released in the atmosphere are hydrogen sulphide and sulphates. Hydrogen sulfide lifetime in the atmosphere is only a few hours. In contrast, SO_2 and sulfates last quite a long time and by the air masses can be carried over long distances.

Actually, the atmospheric concentration of sulfur compounds in the air in Europe almost undoubtedly depends on the proximity of pollution sources. The comparatively unpolluted parts of Europe (12% of the territory) are characterized by SO_2 concentration of 0.35 μg/m^3 (converted to elemental sulfur). In a slightly polluted environment SO_2 concentration is 3.5 to 4 μg/m^3. In heavily contaminated areas SO_2 concentration in the air can reach 50 μg/m^3.

The main source of anthropogenic sulfur dioxide is burning of fossil fuels. All fossil fuels include sulfur, either as organosulfur compounds, or to a lesser extent as elemental sulfur and hence, as a result of fuel combustion, sulfur(IV) oxide is formed.

$S + O_2 \rightarrow SO_2$

SO_2, which is released into the atmosphere as a result of various anthropogenic processes, oxidizes forming sulfur(VI) oxide SO_3.

$SO_2 + O \rightarrow SO_3$

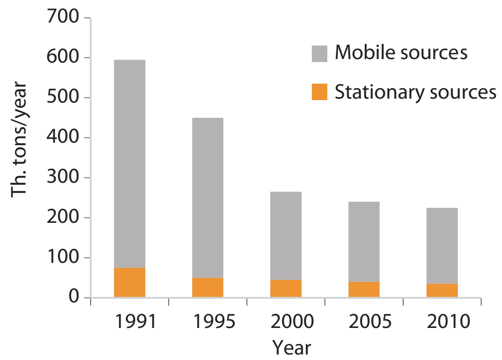


Figure 7.11. Sulfur dioxide emissions from mobile and stationary sources in Uzbekistan

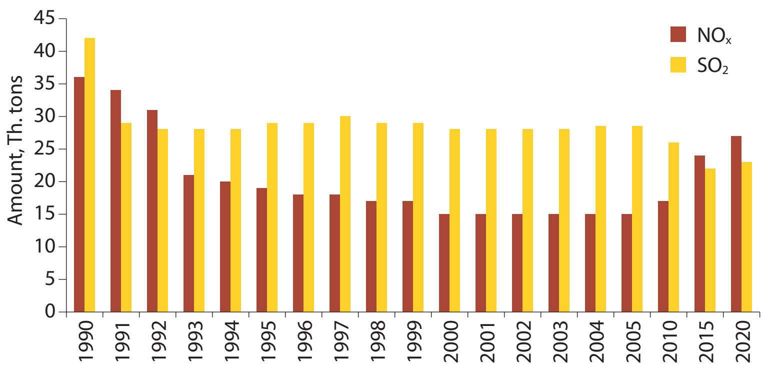


Figure 7.12. Sulfur dioxide and nitrogen oxide emission amount variability in Latvia, 1990–2001 and emissions forecast until 2020.

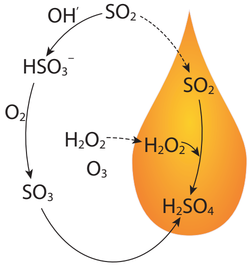


Figure 7.13. Sulfur dioxide oxidation reaction sequence in the atmosphere

Sulfur trioxide – SO_3 readily reacts with atmospheric water vapor to form sulfuric acid solution.

$SO_3 + H_2O \rightarrow H_2SO_4$

The average lifetime of SO_2 in the atmosphere is 5 days and it is accelerated by the presence of nitric oxides, aerosols, hydrocarbons (Figure 7.13).

As the substances of alkaline character – metal oxides, carbonates, ammonium ions, ammonia – are also released into the atmosphere, the reactions take place which result in formation of a corresponding metal or ammonium salts. In addition, the oxidation of SO_2 in the troposphere takes place also in a liquid phase, that is, SO_2 dissolves in water – water drops; i.e., rather than SO_2, in the oxidation process participates sulphurous acid H_2SO_3 or hydrogen sulfites HSO_3. Particularly stable aerosols are formed, if the oxidation processes take place in the liquid phase, SO_2 and their oxidation product transformations are interrelated.

The compounds formed by oxidation of sulfur dioxide fall both in form of rain and snow (wet deposition), as well as dust (dry deposition). An important part of the sulfate-ion containing substances falls particularly in the form of dust particles.

Since 1990, the annual total sulfur dioxide emissions in Latvia have fallen significantly. If at the beginning of the 1990s it was due to the slowdown in the economy, then as of 1996, in the years of economic upturn, an important contribution to the reduction of air pollutant emissions was brought by application of new environmental laws and regulations providing for implementation of measures to minimize air pollution and improve air quality.

The main sources of sulfur dioxide emissions are the energy industry, namely, the production of energy by burning different fuels. The intensity of contamination greatly depends both on the process of combustion, as well as on the fuel quality. As a result of coal combustion, about 70% of the total anthropogenic emission amount is released into the atmosphere. The sulfur compound content of coal is between 1.0% and 4%. In oil sulfur content is between 0.3% and 3%. In industry sulfur dioxide is produced by burning of sulfur, hydrogen sulfide, as well as by burning of metal sulfides. Again, these processes are sources of SO_2 emission.

Sulfur dioxide is released into the atmosphere also in the coal and oil refinement process, in the production of sulfuric acid, by burning household waste. In Latvia the main source of sulfur dioxide is the so-called stationary sources of emissions – energy facilities. Of the most important environmental pollutants, SO_2 emissions are the largest.

Fuels, primarily burning fossil fuels, are considered to be a source of the major formation process of several environmental pollutants (Figure 7.14). In the burning process of fossil fuels the formation of sulfur compounds takes place, and the reaction between the air-forming gases – nitrogen and oxygen – in high

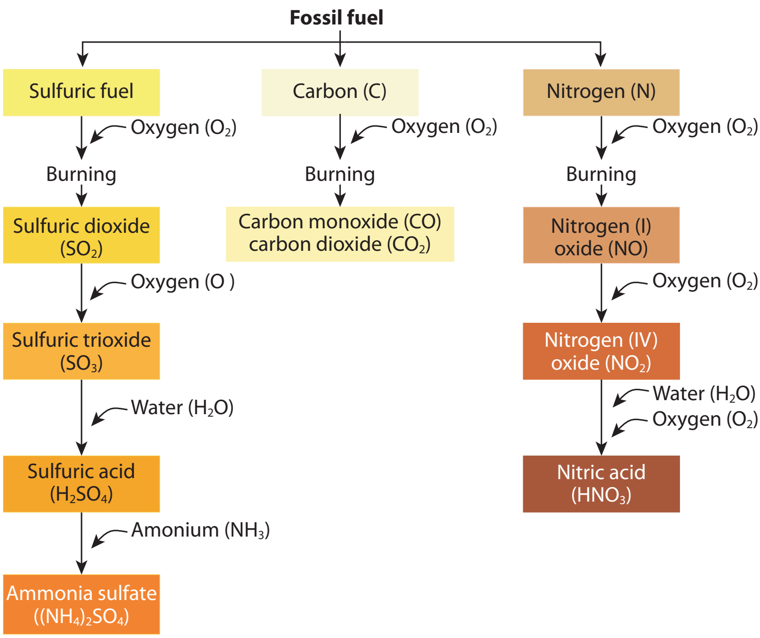


Figure 7.14. Pollutant formation as a result of fossil fuel combustion

temperatures forms other environmental pollutants, but as a result of the fuel-forming organic compound transformation carbon dioxide is formed.

Sulfur dioxide is a colourless gas with a sharp odour. Sulfur dioxide at high concentrations causes severe respiratory irritation. Since sulfur dioxide is easily soluble in water, during the inhalation it sorbs in the mucous membrane of the nose and trachea, whereas if the sulfur dioxide is in the form of an aerosol, it enters the lungs. This is precisely one of the factors that determines the harmful London-type smog exposure, because this type of smog is formed in humid air and is characterized by high dust content.

When sulphur dioxide reaches the concentration of 500 mg/m^3 (daily average), the condition of asthma and pulmonary patients worsens. The cases of hospitalization are observed to increase, when sulfur dioxide concentrations reach 750 mg/m^3. During the London smog in 1952 the annual concentration of sulfur dioxide in the air reached 4000 mg/m^3.

Sulfur dioxide negatively affects plant development. High concentrations of sulfur dioxide exposure can cause leaf necrosis (withering), but chronic exposure results in typical chlorosis – a leaf discoloration or yellowing. Sulfur dioxide effect intensifies with increasing air humidity. Sulfur dioxide causes the inhibition of photosynthesis and plant respiration process, and cell membrane damage. The degree of plant damage depends on the nutrient and microelement balance and the buffering capacity of the soil (that is, the presence of alkaline rocks), in which the plant develops. Indirect effect of sulfur dioxide is acidification of environment, when in the result of precipitation pH decline affects the state of plants and forests, as well as the processes in water and the condition of hydro-ecosystems.

Given the hazards of sulfur dioxide, a number of fundamentally different approaches have been developed to control and restrict its release into the atmosphere. Preventive methods focus on the changes in industrial processes and life style so as to prevent the formation of pollutants. The main source of sulfur dioxide emissions is burning of fossil fuels for energy purposes, hence, the effective method of restricting SO_2 emissions is the change of the energy production systems, namely, the transition to energy sources with a low environmental impact and characterized by an acceptably high degree of safety.

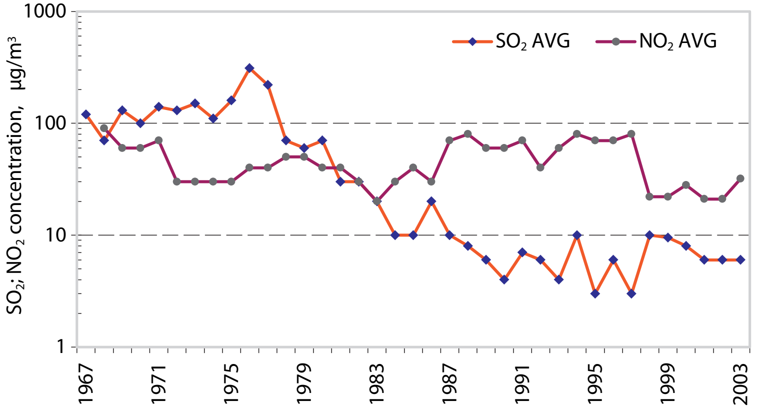


Figure 7.15. Characterisation of atmospheric air pollutant concentration changes in the air of Riga

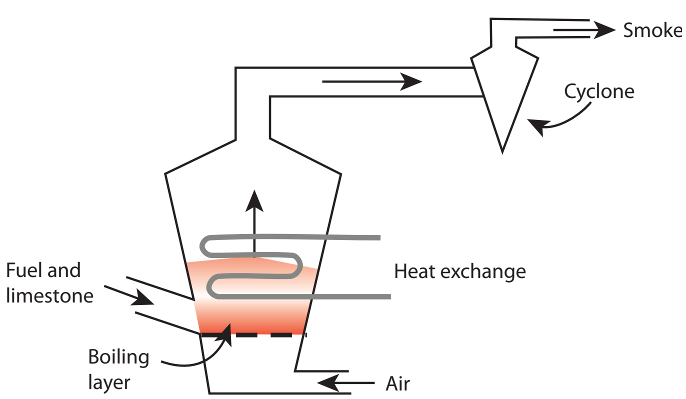


Figure 7.16. Example of a fuel combustion plant, whose operation allows for a significant reduction in SO_2 emissions – a device for burning fluidized layer in the presence of limestone additives, providing exhaust gas decontamination.

Since there are certain industries, which are particularly large consumers of energy, (glass, chemical, building material production), changes in production processes particularly in these areas can significantly reduce SO_2 emission. Energy conservation also indirectly contributes to the reduction of sulfur dioxide emissions. All these measures are realized in the framework of national environmental and industrial policy, balancing the state (population's) economic interests, using such instruments as the tax policy and legislative initiatives. A preventative approach is also switching to low-sulfur fuels (<1% S), gas, nuclear or alternative energy sources.

Clearly, it is possible to lower the sulfur dioxide content in the exhaust gases. First of all, it can be achieved by lowering the sulfur content of the output fuel – coal, oil. About half of the sulfur content of coal can be found in the form of pyrites and up to 80% of it can be removed by grinding the coal and removal of iron compounds, using magnetic separation of iron compounds in a magnetic field – magnetoseparation. Organic substance-related sulfur separation is considerably more complex and broaches the need to convert coal in gaseous fuel (coal gasification) or liquid fuel. Oil can be cleaned of sulfur compounds during its thermal refinement process, however, this approach only allows to reduce the sulfur content. In any case, fuel desulfurization is an expensive process.

An effective solution to reduce sulfur oxide emissions is fuel combustion process optimization, such as using the fluidized bed method. In this case, coal and limestone particles crushed to certain sizes with adjustable air flow are maintained at the level of fluidized bed and already in the process of burning sulfur dioxide is fixed, and gypsum is formed as the end product of the process.

$CaCO_3 \rightarrow CaO + CO_2$

$2CaO + 2\,SO_2 + O_2 \rightarrow 2\,CaSO_4$

$CaO + SO_2 \rightarrow CaSO_3$

This fuel combustion process is very efficient, easy to control and it allows to lower not only sulfur dioxide content, but also other substances in the exhaust gases. In general, this method allows reducing SO_2 and dust content even up to 5% of its initial volume.

It should be noted that there are ways to reduce sulfur dioxide exposure in the immediate vicinity of its emission source, improving the dispersion of exhaust gas in the atmosphere.

Table 7.2. Annual average concentration of air pollutants, μg/m³

City	SO_2	NO_2	Dust
The most common indicators in European cities	20-50	40-60	60-70
European guiding value	40-60	30	40-60
Riga	10-30	45-75	100-200

Of other sulfur compounds whose presence in the air can adversely affect its quality, hydrogen sulfide H_2S should be noted. As a result of natural processes rather large quantities of hydrogen sulfide are released in the environment. The main sources of its natural emission are volcanic gases and decomposition of living organisms. High hydrogen sulfide content is observed in natural gas (up to 15%, Leke – France, Astrakhan – Russia). In small quantities it escapes into the atmosphere as a result of processes that take place in continental shelves, marshes and elsewhere due to decomposition of organic matter. Hydrogen sulfide concentration in the air on average equals 6 μg/m^3.

In industry, hydrogen sulfide is incorporated into the composition of coke gases and water gas, and as an admixture it may be generated in oil refining, as well as the manufacturing processes of artificial silk, cellulose, rubber and dyes. Hydrogen sulfide and organosulfur compounds are released by purification devices.

Hydrogen sulfide is an unstable compound that readily oxidizes, reacts with metals. Depending on the oxidizer, the oxidation processes lead to sulfur or sulfur oxides. Hydrogen sulfide is easily soluble in water. The toxic effect of hydrogen sulfide is determined by its ability to block the enzyme activity by binding to the constituent metal ions in stable sulfides. Hydrogen sulfide sensing threshold is 0.075 to 0.1 mg/m^3, and contact with it numbs the sensory organs rather quickly. In practice, the poisoning of hydrogen sulfide can take place as a result of contact with sewage systems, as well as in chemical laboratories and enterprises. Thus, the key issue to protect people from exposure is proper ventilation and, if necessary, airing in the rooms where hydrogen sulfide may accumulate.

7.2. Nitrogen compounds in the atmosphere

Nitrogen constitutes 76% of the weight of the atmosphere, however, in hydrosphere and lithosphere the amount of nitrogen compounds is significantly lower. Nitrogen compounds in the atmosphere are found in the form of many compounds: N_2O, NO, N_2O_3, N_2O_4, N_2O_5, NH_3, ammonium salts. Other nitrogen oxides are either formed as intermediate products in various reactions or are unstable and decompose rapidly:

Nitrogen (I) oxide (N_2O) is naturally present in the atmosphere as a product resulting from a variety of biologic transformations. The amount of anthropogenic emissions of N_2O is relatively small (Table 7.3) and, subsequently, the pollution of nitrogen (I) oxide, particularly in view of its low toxicity, is not considered to be hazardous to living organisms. This substance is odourless and tasteless, chemically inert. In small amounts it is released in nitric acid production process, it is used as an anaesthetic agent in medicine, and as an inert gas in technology. Toxic effects have not been established. N_2O is released into the atmosphere mainly as a result of nitrogen and organic matter decomposition reactions and its annual emissions amount to 100 million tons a year. The total amount of N_2O in the atmosphere is 2000 million tons. Its life period is 20 years, and in the last decades N_2O content in the atmosphere is increasing by 0.3% per year. Therefore, the N_2O is considered to be one of the most important greenhouse gases.

Table 7.3. Nitrogen (I) oxide sources in the environment

Emission sources	*Tg N_2O-N/per year*
Natural sources	
Oceans	1.4-2.6
Tropical soils	2.7-5.7
Temperate climate sources	0.05-2.0
Anthropogenic sources	
Use of fertilizer	0.03-3.0
Biomass incineration	0.2-1.0
Combustion of fuels	0.3-0.9
Production	0.5-0.9

Nitrogen oxide (II) NO is a colourless gas, odourless, non-flammable. However, in the air it easily oxidizes to NO_2 and therefore the sum of both oxides NO_x is usually looked at. Nitrogen (II), as well as nitrogen (IV) oxide is highly toxic. Nitrogen (II) oxide is mainly formed due to a variety of high temperature processes, as a reaction of oxygen with nitrogen.

$$N_2 + O_2 \rightarrow 2NO$$

$$N_2 + 2O_2 \rightarrow 2NO_2$$

From the point of view of environmental pollution, special attention should be given to nitrogen (II) oxide NO and nitrogen (IV) oxide NO_2.

The reaction time depends on the temperature, respectively, the amount of energy input.

At 2000 °C temperature NO, N_2 and O_2 molecule cross-reaction is at equilibrium. The intensity of NO formation is also affected by how quickly the formed molecule is removed from the reaction zone. Thus, the nitrogen oxides are formed in all processes that occur at high temperatures: burning, spark discharge, plasma processes, and explosions.

Nitrogen oxides are formed by working car engines (Figure 7.17). Fuel-air mixture in the cylinder of the car engine is compressed (compression), an electric spark ignites it, and the combustion (explosion) leads to a high temperature (>1000 °C), where as a by-process a reaction occurs between the air forming gases – nitrogen and oxygen to form NO. After fuel combustion in the cylinder, the produced gas mixture is pushed out of the cylinder and it cools down relatively quickly, retaining the formed NO quantity.

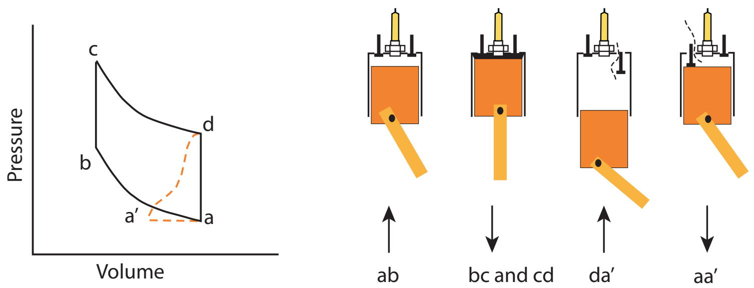


Figure 7.17. The internal combustion engine work cycle

Once in the atmosphere, nitrogen oxides become involved in various chemical reactions. Nitrogen oxides, which have entered stratosphere, may participate in the ozone disintegration cycle. A significant source of nitrogen oxides in stratosphere are the supersonic aircrafts. At the same time, the nitrogen oxides in the stratosphere can undergo alterations that result in regeneration of particles with reactive capacity that are able to produce ozone. An important role in the atmosphere is played by the processes leading to the formation of nitric acid, HNO_3.

$NO_2 + HO^{\cdot} \rightarrow HNO_3$

From the labour safety point of view a danger may be caused by increased discharge of nitrogen oxides during the electric welding processes, especially in confined spaces. Nitrogen oxides are also formed in the combustion of nitrogen organic compounds present in the fuel, and this process can take place at significantly lower temperatures than NO_x thermal synthesis.

The resulting HNO_3 mainly falls down by precipitation in the form of both acid and salts. Of nitrate salts, ammonium nitrate (NH_4NO_3) is mainly found in the atmosphere. Since the photochemical transformations of nitric oxides and also their elimination from the atmosphere take place rather quickly, the acidification of precipitation as a result of nitrogen presence has a significant impact on the regions near to the pollution sources.

Taking into account the significant amounts of nitrogen oxide produced (total global emissions of 86 million tons / per year), they can adversely affect the on-going processes in the environment, as well as human and animal health.

Overall, nitrogen oxide emissions in Europe are now among the most dangerous contemporary environmental pollution factors. These issues are especially topical in the Baltic Sea region countries, where the nitrogen compound load determines many of the negative processes that take place in this region. Thus, a matter of actual nitrogen oxide emission control – the restraint – becomes urgent.

Traffic of motor vehicles is considered to be one of the major sources of nitrogen oxides, which directly affects the air quality in cities (Figure 7.18) and the growing number of cars in the streets is increasing the nitrogen oxide concentration.

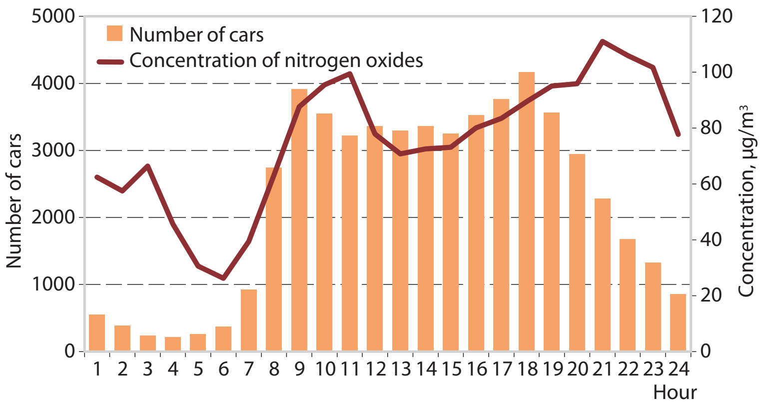


Figure 7.18. Nitrogen oxide concentrations and changes of traffic intensity in the streets of Riga (Gertrude Street, August)

In 2005, the transport in Latvia created already as much as 52% of the total NO_x emissions. The relative impact of transport on

NO_x emissions has increased, while energy production impact has been reduced almost by half, which is explained by the significant increase in the number of vehicles and the fact that natural gas is used more and more for energy purposes. Since 2000, the increase in energy production has gradually scaled up the nitrogen oxide emissions from the combustion plants. The established maximum allowable nitrogen oxide emission in the air for 2010 was 61 kilotons.

One of the major contemporary sources of NO_x emissions is traffic (Table 7.4). The traffic can be considered a major source of emissions of nitrogen oxides particularly in the urban environment.

Table 7.4. Nitrogen oxide emissions and major sources of emissions in Latvia, tons per year

Sector / Year	*1990*		*2000*		*2005*	
	Emission	*Proportion, %*	*Emission*	*Proportion, %*	*Emission*	*Proportion, %*
Energy production	1648	24	696	18	635	1544
Fuel use and production	1022	15	341	9	426	1037
Transport	2660	40	1903	50	2150	5228
Commercial, household and other incineration unrelated to production	906	13	520	13	529	1285
Industrial production processes	346	5	284	7	319	775
Agriculture and forestry	22	0.3	41	1	0.4	1
Total emissions	6604	100	3788	100	4112	100

Nitrogen oxide emissions from traffic are significantly more difficult to control because the lowering of fuel – air mixture temperature leads to an increase of CO and hydrocarbons in the exhaust gases. The applied methodology includes electronic ignition timing control, recirculation of exhaust gas enriched with fuel, however, one of the most effective methods is considered to be the catalytic reduction of nitrogen oxides in the presence of CO and hydrocarbons with their subsequent oxidation, additionally supplying air.

Of the other nitrogen compounds that are relevant regarding the environmental pollution, the ammonia should be mentioned. Relatively large quantities of ammonia are released into the environment as a result of different natural processes. The main natural sources of ammonia emissions are the organic matter decomposition processes.

Elevated ammonia concentrations can be found in the human living and working environment, such as cattle, drainage systems, etc. Ammonia is widely used in various technological processes, production of fertilizers, agriculture and as a refrigerant.

7.3. Carbon compounds in the atmosphere

To denote the air pollutant concentrations often their concentrations are expressed in parts of volume and number: respectively: parts per million – ppm; – parts per billion; – parts per trillion. This designation refers to the concentration of the substance in the total air quantity of 300 ppm means that the million of gas molecules constituting the air contains 300 molecules of the respective greenhouse gas, or a million volume units of air (such as cubic centimetres – cm^3) contains 300 cm^3 of the respective gas.

Carbon is the most important element forming the living organisms. Carbon in the atmosphere is in the form of carbon monoxide (CO), carbon dioxide (CO_2) and methane (CH_4), and the presence of these gases has a significant impact on the atmospheric properties (heat balance) and hence the climate on the Earth. Therefore, the growing carbon monoxide emissions may become a factor that can adversely affect the environmental processes. It is estimated that over the past 100 years, anthropogenic CO_2 has increased by an average of 2.5% per year. CO_2 content in the air is also affected by deforestation. During the 20th century carbon dioxide emissions have significantly increased, and in the period from 2000 to 2005 they had already reached an average of 26.4 GtC CO_2 per year. It is estimated that, depending on the population growth trend, the volume of carbon dioxide emission can reach up to 35.8 GtC / per year in 2100.

Carbon dioxide concentration in the atmosphere has risen from 280 parts per million in the pre-industrial era to 379 parts per million in 2005. Researching the air enclosed in the continental glacier ice, it has been proved that the concentration of CO_2 today is significantly higher than it was during the last 650 000 years (180-300 ppm). Other greenhouse gas concentrations (e.g., methane CH_4, nitrogen (I) oxide N_2O) have also gon up significantly.

Carbon monoxide CO (charcoal fumes) can be important in the context of the human living and working environment pollution. The total amount of CO in the atmosphere of the Earth is evaluated at 530 million tons, and it remains in the atmosphere from 36 to 110 days. The main sources of emission are various natural processes: decomposition of living organisms (especially green plant chlorophyll decomposition), metabolic processes of plants and especially of marine organisms. A serious source of carbon monoxide is a variety of photochemical processes (especially methane oxidation), in which CO is released as a by-product.

Anthropogenic carbon monoxide emission sources account for about 6% of its total quantity. The main sources of anthropogenic emissions are the internal combustion engines, their exhaust gas, as well as products of fossil fuel incomplete combustion. Particularly dangerous in the context of the human living environment pollution is carbon monoxide. In everyday life the sources of danger can be gases resulting from incomplete combustion in furnaces, stoves and other heating systems, automobile exhaust fumes, particularly in confined spaces.

Carbon monoxide transformation processes are predominantly mediated by hydroxyl and hydroperoxide radicals via singlet oxygen or ozone. The prominent role of soil in binding carbon monoxide should also be noted. It is determined by the activity of soil microorganisms.

Given the high toxicity of carbon monoxide, especially in the human living environment, it is essential to reduce the emissions resulting from various combustion processes. First of all, it can be achieved by controlling the internal combustion engine gas composition. CO content declines, when «leaner» (poorer in fuels) air/fuel mixtures are used and the exhaust gas catalytic oxidation is carried out.

The toxic effect of carbon monoxide is based on its ability to replace the oxygen in haemoglobin, forming carboxyhaemoglobin, which is unable to transport oxygen. Carboxyhaemoglobin formation reaction is reversible, therefore, in case of poisoning by carbon monoxide inhalation of air or pure oxygen can restore the ability of haemoglobin to carry oxygen.

If carboxyhaemoglobin reaches 10-20% of the total haemoglobin in the blood, the poisoning symptoms include mild headache, fatigue, discomfort, at 20-30% dizziness can start to appear, loss of consciousness can occur, but if 60-70% of haemoglobin are converted into carboxyhaemoglobin, the outcome is lethal (Table 7.5).

Table 7.5. Blood haemoglobin saturation with CO dependence on the CO concentration in the air (assuming that polluted air is inhaled for 4 hours)

Concentration in the air, %	0.01	0.1	1.0
The amount of haemoglobin saturated with CO, %	17	60	90

It should be emphasized that the toxic effect of CO is highly dependent on the amount of air inhaled, respectively, the nature of work that a person performs. The hazard of poisoning with carbon monoxide is increased by the fact that it is a colourless gas, odourless and tasteless, which cannot be felt, but even a negligible amount can affect a person's ability to act. CO content can be determined by its reaction with mercuric oxide, CO ability to sorb in the infrared region of the spectrum (this principle is widely used in automobile exhaust gas analysis), and gas chromatography.

7.4. Dust and aerosols in the atmosphere

Atmospheric air can contain the particles of most diverse type, composition and size. Their size can vary from micron to parts of millimetre. Finer particles (size $<10\ \mu m$) are called aerosols, but the coarser ones are named the dust. The micro drops of solutions (fog) also belong to the aerosols. Aerosols can be classified according to the source, which can be land, sea (primary aerosols) or human activities, as well as the chemical or mechanical formation processes of aerosols (secondary aerosols). The main sources of aerosol formation are various natural processes – the soil, entry of its constituent mineral particles into the atmosphere as a result of wind activity, dust storms, volcanic eruptions, forest fires, evaporation from the sea and ocean surface (salt sprays or aerosols are formed). However, modern human behaviour results in a large amount of aerosols and dust in the air. The processes such as energy production, construction material production and mining, agriculture, air transportation and other are the main anthropogenic sources (Table 7.6).

Table 7.6. Sources of aerosol and dust emission

Sources	*10^6 t/per year*
Natural	
Sea salts	1000
Soil	200
Volcanoes	4
Forest fires	3
Anthropogenic	
Coal combustion	36
Oil combustion	2
Wood incineration	8
Waste incineration	4
Agriculture	10
Manufacture of cement	7
Manufacture of iron / steel	9
Other	16

Aerosols can be formed, and the content of particles in the air may change due to a variety of chemical reactions. In this context the first to be mentioned is the important role of sulfur and nitrogen oxides in these processes. Since the airborne solid matter particles serve as condensation centres for water vapour, virtually all of these reactions take place in the aquatic environment or in the presence of water, and the typical examples of these are related to the formation of acid rain.

Aerosol formation under the influence of atmospheric air is also affected by a number of mechanisms and physical processes:

1. Coagulation and sedimentation. The smallest of aerosol particles can stick together to form larger aggregates. This process affects the stability of aerosols and dust, and the time it stays in the

atmosphere. Particles with dimensions smaller than 0.01 μm, are subject to Brownian motion and their fall happens very slowly, but the particles that are larger than 10 μm fall quickly.

2. Dust and aerosols in the atmosphere (0.1-20 μm) serve as water vapour condensation centres and thus can be removed from the air.
3. Larger dust particles can collapse to form smaller size aerosols. This process is called dispersion.

Since the spray or dust particles have a large specific surface area, they can sorb atmospheric gases, chemicals, microorganisms and water vapour. Sorption process thereby determines the rather complex composition of aerosols. If the sorption results in a change of aerosols' chemical composition, the process is called chemisorption, which occurs, for example, when sulfur, nitrogen oxides react with iron or aluminium oxide-containing aerosols.

Table 7.7. Number of days when the maximally permissible concentration of dust in air was exceeded, %

City	2008	2009	2010
Almalik	21	19	14
Bukhara	38	43	44
Gulistan	21	22	26
Navoi	30	8	4
Nukus	71	73	69
Taskhent	22.74	9.32	13.15

Aerosols which enter the atmospheric air can serve as catalysts for various chemical reactions, such as zinc and iron oxide-containing aerosols can catalyze the oxidation of sulfur dioxide into sulfur trioxide.

Overall, the chemical transformations that occur with aerosols can significantly alter their properties and composition. For example, cement production dust, when released into the atmosphere, significantly reduces the sulfur and nitrogen oxide content, forming the respective calcium and magnesium salts, and thus affecting pH of the atmospheric precipitation.

Dust and aerosol particles also are electrically charged. Aerosol and dust chemical composition can differ quite considerably depending on their source. Aerosols may consist of water-soluble ions or particles which are almost water insoluble. At the same time, the aerosol composition analysis allows to identify the sources of aerosols. Aerosols of natural origin are mostly composed of potassium, aluminium, silicon, sodium, iodine, iron, chlorine and

The most probable aerosol constituent elements come from the following sources:
Al, Fe, Ca, Si – soil erosion,
C – incomplete combustion of fossil fuels;
Na, Cl, SO_4^{2-} – sea, ocean aerosol, the burning of fossil fuels;
Pb – fuel and waste burning.

carbon compounds. Heavy metals and complex organic substances in the aerosol composition suggest that their formation has occurred due to human activity.

Atmospheric aerosols and dust can significantly affect the Earth's climate. This is evidenced both by the Earth's long-term climate change analysis and the impact on the climate of dust spillage in the atmosphere from the eruption of volcanoes.

Dust and aerosol effects on the human body are determined by the particle size (Figure 7.19). Coarser particles (dust) are mainly detained in the nasal cavity and upper respiratory tract, but especially fine particles (with sizes of less than 10 micrometres) reach the lung alveoli, and may even fall into the blood circulatory system. Airborne dust and aerosol inhalation can cause inflammatory processes in the respiratory system, increase the risks for the development into respiratory diseases, particularly chronic, and suppress the immune system.

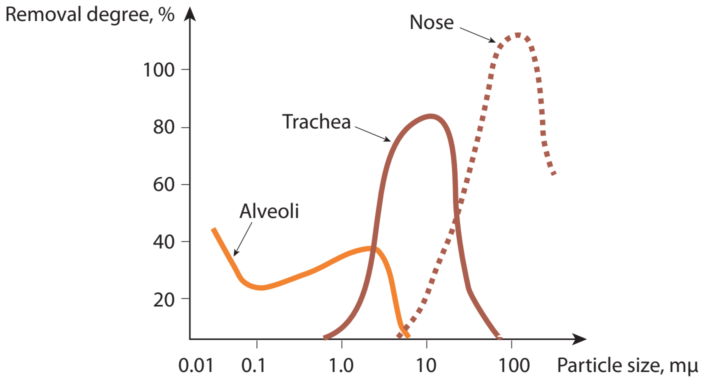


Figure 7.19. Retention of the aerosols in the human respiratory system depending on the size distribution

A significant group of aerosols are those of an organic composition. Their source can be either natural processes (plants, forest fires, decomposition of organic matter), or anthropogenic processes. Human health can be particularly negatively affected by metals (Pb, Hg, Cu, Ni, Be), radioactive isotopes and organic matter present in the aerosol composition. Aerosol effect most rapidly manifests itself when the particles are inhaled and held in the lungs (coarser dust particles are retained in the nasal cavity and upper airways, while the finer particles may be exhaled). Such aerosols are called inhalable aerosols. These aerosols have the following effect:

1. When the substances sorbed on aerosol surface desorb and move into the blood or lymphatic system. This effect is particularly characteristic of various combustion products. The aerosols which are products of combustion consist of carbon, and the

aerosol surface usually holds quite high concentrations of different organic substances, which are created both due to incomplete combustion, as well as thermosynthesis process. Such aerosols contain the following groups of substances:

- *aliphatic hydrocarbons*. Usually, they are very long-chain alkanes with carbon atom numbers reaching even 24;
- *aromatic hydrocarbons*. Aerosols of combustion contain not only low molecular weight aromatic hydrocarbons (benzene, toluene), but also the polyaspartic hydrocarbons – benzo[a]pyrene, chrysene, benzo[a]fluoranthene, benzo[a]anthracene, naphthalene, anthracene and others. Desorbing and entering the body, these substances can cause malignant tumors not only in the lungs but also in other organs;
- *aldehydes* and *ketones*, as well as *carboxylic acids*;
- *polyaromatic* and *heterocyclic compounds*, such as benzacridine, dibenzacridine, which also are characterized by highly carcinogenic effect;
- organochlorine compounds.

2. Particularly fine particles can get into the blood or lymphatic system from the lungs. An example of such particles is asbestos fibres.
3. Aerosol particles can remain in the lungs, become calcified, thus causing permanent irritation. This type of aerosol exposure is inherent to occupational diseases – asbestosis and silicosis, caused by inhalation of air polluted by mineral particles.
4. Micro-organisms, bacteria or fungi residing on aerosol and dust particles can cause allergic reactions and cause disease.

Aerosol retention in the human respiratory system depends on the size distribution of particulate matter.

Pollen, dust of wood, flour and other organic substances can be viewed as a special group of aerosols. Since these substances are organic, their composition differs significantly from the composition of the traditional dust, but among the potential effects on human health the ability of these aerosols to cause allergies should be noted.

Aerosols and dust may adversely affect the plants, too. This effect is characterized by the process of photosynthesis inhibition and effects of toxic substances, as they desorb.

In the Uzbekistan major sources of dust are – loose dusty soils and surfaces of salinized soils of Karakum, Kizilkum and Aralkum (dry part of Aral Sea) deserts. Aeolian drift of sand and salt from the dry bottom of Aral Sea yields 40-45 million tons/year, besides, the main salt and dust erosion occurs within 300 km of coastal strand. The amount of dust, which falls out on the soil in Juznoje Priaralje, is ten times bigger than in the irrigated zone. The composition of dust from Aral Sea includes sulfate salts up to 25-48%, chlorides – 18-30%, carbonates – 10-20%.

The total capacity of anthropogenic sources of solid particle emissions into the atmosphere in the Republic is considerably lower than of the natural ones and is evaluated at 1.311 millions of tons per year. The share of solid particles in anthropogenic emissions is not high and contributes 16% for industrial sources, and 2% for mobile ones. The total amount of solid particles' emissions in the Uzbekistan from industry is much higher than from the transport.

The main sources of entry of the industrial dust are companies of State Joint Stock Companies «Uzbekenergo», «Uzstrojmateriali», «Uzchlopkoprom». According to the statistical data for the period from year 2000 to 2005, the total emissions of solid particles increased from 88.993 thousand tons to 101.09 thousand tons, but in year 2006 a notable decrease had been observed.

Index of total dust concentration in the atmosphere is being controlled in 18 industrial cities of Uzbekistan. Excessive dust concentration is observed in large cities, in which lives approximately 41% of urban population. The level of air contamination with dust is affected by high natural dustiness and industrial emissions. The city dust characteristically contains soot, which is formed during the combustion processes. The major mass of soot is being washed away by precipitation. In exhaust gasses from automobiles, which contribute in a certain way to dustiness of surface air, small particles with diameter of 0.02-0.06 μm prevail.

Higher specific dust emissions are observed in cities, where cement industry and coal-burning powerplants are mostly located. Dust settling around industrial centres contains various mineral compounds, metal oxides, silicates, soot, fluorides, arsenic oxides, antimony and selenium. Among specific admixtures in dust contents of large industrial cities are metals like cadmium, copper, lead, nickel, zinc and manganese.

Since the aerosol effects on human, animal, plant and building condition may be adverse, and according to mass, aerosols and dusts must be considered the largest group of atmospheric pollutant compounds, it is important to limit their emission in the main areas of aerosol formation, namely, industry and energy production.

To clean exhaust fumes from dust and aerosols several approaches can be used:

1) The simplest method for air cleaning from dust is the sedimentation of dust. Only coarser dust particles (>100 μm) fall out sufficiently fast, and that limits the opportunities for using this method;
2) To clean the air from dust and aerosols, one can take the advantage of the fact that the particle inertia is larger than that of the gas molecules. This principle is used in cyclones and dry centrifuges. In this case, the air to be purified is introduced into a conical cylinder so as to create an air swirl

movement, where the heavier dust particles are thrown back to the cylinder wall. Cyclones are the devices for continuous operation.

3) Filtration of the air to be purified. Aerosols and dust can be effectively removed by filtration of the air mixture to be purified through suitable, such as asbestos, fibres, synthetic material, glass fibre fabric. The filtration efficiency is dependent on the filter material.
4) Scrubbers. In this case, a liquid is sprayed in the air to be purified. The liquid gathers (and if accompanied by an appropriate reagent also reacts with) the dust and aerosol particles. This method is considered to be one of the best from the gas cleaning efficiency point of view, while at the same time it is a costly operation, which results in formation of liquid waste that need to be disposed of, and the use of such approach is not always well founded.
5) Electrostatic purification. The exhaust fumes can be purified, first of all, by charging them during gas flow through the DC high voltage electrical discharge zone, and then through two electrodes. Negatively charged dust and aerosol particles are held up at the positive electrode. This method is effective and inexpensive, and it can be used continuously.

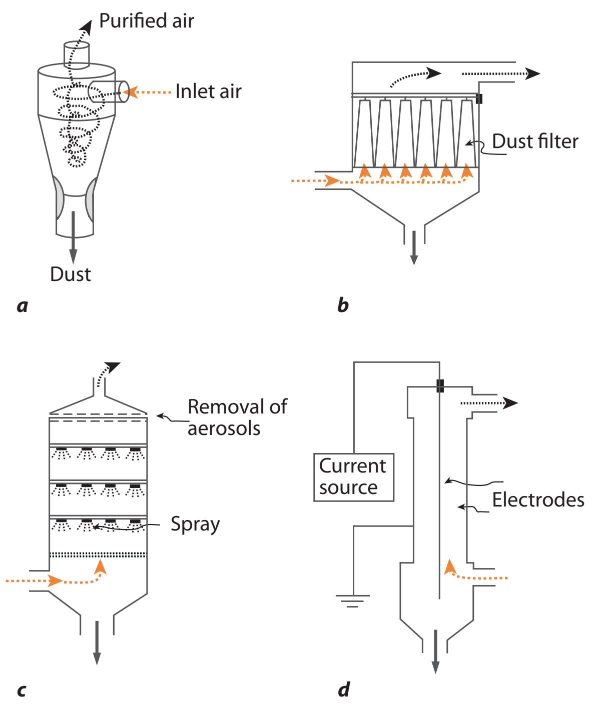


Figure 7.20. Polluted air treatment solutions from dust and aerosols: ***a*** – cyclone; ***b*** – dust filter; ***c*** – scrubber; ***d*** – the electrostatic coagulation

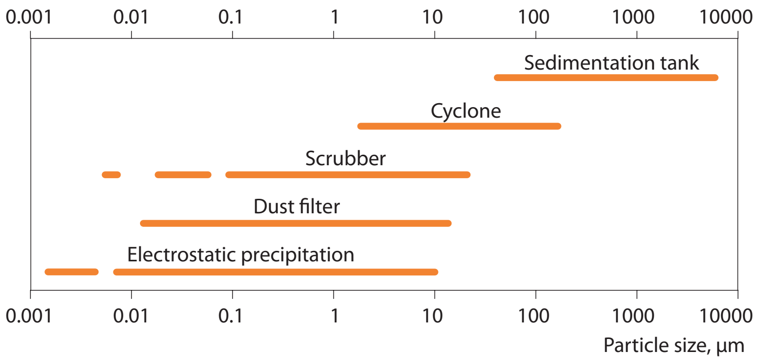


Figure 7.21. Comparison of different technologies for dust and aerosol removal.

The choice of optimal gas treatment methods is determined by aerosol concentration, their composition, presence of other gases, as well as economic considerations.

7.5. Halogenated organic compounds in the atmosphere

Typical air pollutants contained in the atmospheric air composition are various halogen compounds. Since the elementary halogens are very reactive, they are not found in the atmosphere in a free form. However, production processes involve significant amounts of various halogen derivatives, therefore both the living environment and the atmospheric pollution by halogen derivatives is possible. Given the high toxicity of halogen compounds, environmental pollution by halogenated compounds is considered to be dangerous, as these can be discharged, when many halogen compounds are released into the environment. For example, many metal and non-metallic chlorides, which are widely used in the manufacture, in contact with water or damp air intensively form hydrogen halides. Examples of such substances are aluminium, titanium and tin chlorides ($AlCl_3$, $TiCl_4$, $SnCl_4$), as well as silicon and phosphorus chlorides ($SiCl_4$, PCl_3, PCl_5, $POCl_3$).

Among the many environmental pollutants the organohalogens occupy a special place not only for their toxic effect, but also because of the fact that it is this group of substances, which historically enabled understanding of the pollution impact in the biosphere.

Production of synthetic halogenated organic compounds, which started about 50-70 years ago, has now reached significant dimensions and includes many groups of substances, as well as a wide scope of application: industrial production, agriculture, medicine, and the production of substances that are used in everyday life. Already two examples of this group of substances – pesticide DDT and polymer polyvinyl chloride compound shows broad spectrum of features and usability characteristic to organohalogens. However, to talk about the effects of exposure to these substances, one must discuss the structure, areas of use and the main characteristics, as well as the main sources of environmental pollution with halogenated organic compounds. First of all, halogenated organic compounds can be divided into organofluoride organic, chloro-organic and organobromide compounds.

Despite the extensive production, organofluorine compound application range is narrower than that of the chloro-organic substances, which is mainly due to their high cost. The most popular of the organofluorines is dichlofluormethane (Freon). The methane derivatives are: Freon 11 ($CFCl_3$, b.t. 23.8 °C); Freon 12 (CF_2Cl_2, b.t. –29.8 °C); Freon 13 ($CFCl_3$, b.t. –81.4 °C) and ethane derivatives Forane 114 (CF_2ClCF_2Cl, b.t. 3.6 °C) and Forane 113 ($CFCl_2CF_2Cl$, b.t. 47.6 °C).

These gaseous or easily liquefiable substances are mainly used, as follows:

1. as propellants in aerosols (freons are chemically inert, non-combustible, practically non-toxic);
2. as heat carriers in cooling devices;
3. as foaming agents in the manufacture of porous polymers;
4. in microelectronics;
5. in chemical industry.

Such a wide scope of use of these substances is determined by many unique features of freons, among which the first to be noted is the high chemical stability of these substances (they do not break down in the aquatic environment, or when exposed to acids, bases and oxidizers). Freons are also characterized by low acute toxicity: inhalation of freons F11, 12, 22 and other freon vapour (0.5% vol.) for 90 days, 6 hours a day does not result in any symptoms of toxic effects. The maximum permissible concentration in the air for most of the freons is about 1000 mg/m^3, but for liquid freons F11 and F113LD_{50} it is above 15 g/kg.

Furthermore, the other characteristics important from the practical point of view determine the extensive production of freon today. Taking into account the specificity of freon use, most of this volume is dispersed into the atmosphere, where the freon decomposition is slow. At the same time, in the stratosphere under the influence of UV radiation, freon molecules decompose, releasing the halogen radicals, which may subsequently act as catalysts for ozone decomposition reaction. Given the harmful effects of organohalogens, degrading the ozone layer (primarily freons), the production and consumption amount in the European Union Member States (Figure 7.22) as well as in other countries has significantly decreased in the last decades.

Chlorine derivatives C_1 and C_2 belong to low molecular weight organochlorine. Typically, this group of substances includes methane chlorine derivatives (carbon tetrachloride CCl_4, chloroform $CHCl_3$, methylene chloride CH_2Cl_2, methyl chloride CH_3Cl), chlorine derivatives of ethane or ethylene. These substances form a separate group, taking into account the production of substantial size, and the similar toxicological spectrum. Halogenated hydrocarbons are obtained both by the direct chlorination of hydrocarbons, and by chlorination in the presence of atmospheric oxygen as an oxidizing agent. Typical lower chlorinated hydrocarbons are liquid substances (with the exception of methyl and vinyl chloride, which are gases, and hexachloroethane, which is solid). Annual production of vinyl chloride ($CH_2{=}CHCl$) amounts to 10 million tons. 1,2-dichloroethane is also produced in significant quantities (13 million tons per year) as well as carbon tetrachloride (1 million tons per year). Large amounts of trichalomethanes (THMs) are formed as a result of water chlorination. These substances may be also formed as a result of various natural processes. It is assumed that burning fossil fuels and biomass release 5×10^6 tons of methyl chloride per year into environment, but up to 40 000 tons of methyl chloride are formed in the ocean and sea algae life processes.

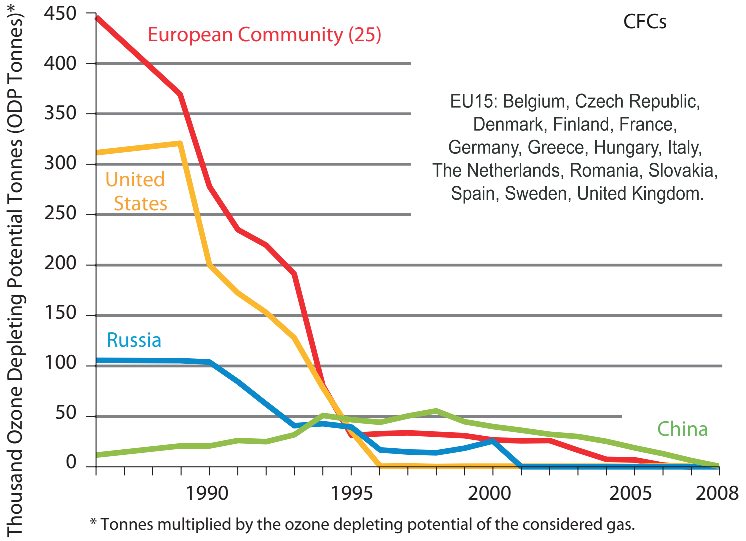


Figure 7.22. Global production of main ozon depleting substances

Lower halogenated hydrocarbons are widely used as solvents in the manufacture of polymers (vinyl chloride). The large amounts and mode of use result in release of significant volumes of these substances into the environment, and it can affect human health in the living and working environment. Lower molecular mass chlorinated hydrocarbons, when inhaled, act as anaesthetic substances, which can easily lead to poisoning, especially affecting the liver. In some chlorinated hydrocarbons the carcinogenic effects have been proven.

7.6. Urban air pollution problems

Air quality in urban areas requires particularly careful consideration. This is determined not only by the fact that the urban environment is densely populated, but also because the cities have large industrial territories and intensive traffic. Thus, the characteristic pollution can be observed in the urban environment, due to the high concentration of pollution sources and in many cases, the limited options for pollution dispersion.

Figure 7.23. The nature of dispersion and circulation of air masses and pollutants over urban areas

The pollutant dispersion process in the urban areas is activated by the movement of air masses due to uneven warming of the Earth surface. As the city buildings and road surfaces intensely absorb heat, in these territories the so-called «heat islands» are formed. This effect maintains the typical air mass circulation models in the cities that facilitate dispersion of pollutants. In this case, the contaminants (especially in the form of dust and aerosols) drop at a certain distance from the city limits creating a heightened pollution zone.

An important role in pollution dispersion is played by a vertical scattering process of air masses. Under normal circumstances, at the higher levels the air mass temperature decreases. However, there may be situations when the air temperature rises as the distance from the surface of the Earth increases. This state of the atmosphere is called inversion, and it can be quite stable. In case of inversion the release of contaminants is hindered, and results in concentration of these substances in the places of discharge.

Inversion can be caused by two types of processes: first, with the advance of warm air to the air mass with a higher pressure and lower temperature or at night, as a result of the Earth surface losing heat. The first type of inversion processes take place as the air masses descend on areas with increased atmospheric pressure. Under these conditions, air pressure and temperature of the air mass, which is subject to the inversion process and is located in the upper boundary, is higher than at the lower limit. If the air mass

The word 'smog' appeared about 70 years ago to describe a mixture of smoke and fog, which formed above London due to the temperature inversion processes. Later, this term was applied to certain adverse processes in the polluted atmosphere. Today, two types of smog are distinguished:

1. the smog associated with the presence of smoke and soot, and a high SO_2 content ('London smog');
2. the smog caused by a vehicle exhaust photochemical transformation reactions ('Los Angeles smog').

descends slowly, a positive temperature gradient is formed in its volume and the mass of air that is subject to the inversion process, forms a shape similar to a huge lid covering the air mass below it. This type of inversion process may last several days, and there have been some cases of mass poisoning of population as a result of atmosphere pollution directly related to the inversion phenomenon.

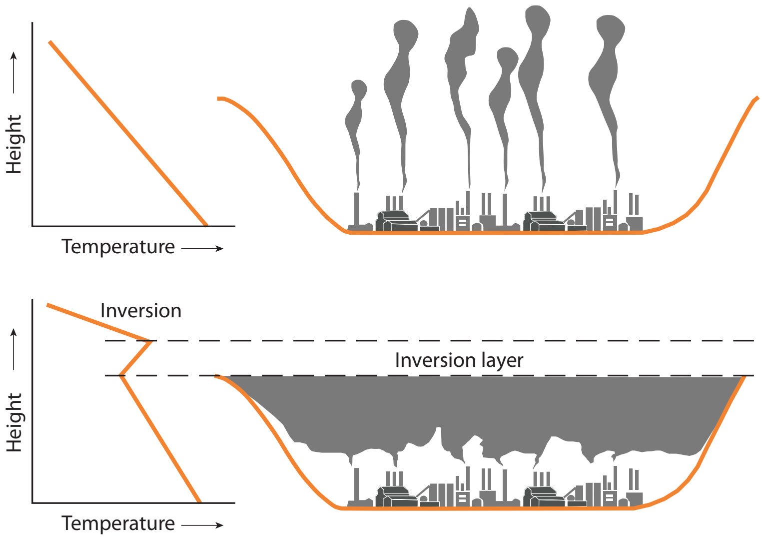


Figure 7.24. The role of inversion processes in limiting the dispersion of air pollution formed in urban territories

There are the following features characterising the photochemical smog:

1. it is formed in a clear, sunny weather at a low air humidity;
2. chemically the smog atmosphere acts as an oxidizing agent;
3. it causes the irritation of mucous membrane and the upper respiratory tract, adversely affects plants and animals;
4. it is seen as a bluish haze or mist.

For the second type of smog, the prerequisite is a variety of photochemical processes in the atmosphere, so it is often called a photochemical smog.

The main factor that determines formation of the photochemical smog is air pollution with nitrogen oxides and hydrocarbons in the presence of intense ultraviolet radiation. The main source of nitrogen oxides and hydrocarbons in urban air is emissions from the vehicles. When these emissions enter the air, a series of different transformations can begin under the impact of intense ultraviolet radiation. These chains of transformations determine the rather characteristic process of changes in the content of pollutants in the photochemical smog, where the content changes of primary pollutants (NO, CO, hydrocarbons) and secondary pollutants (O_3, aldehydes) can be observed over the day and night. The character of these changes allows one to follow the photochemical smog formation mechanism and to understand what processes determine the appearance of one or another substance in the air.

Obviously, the crucial role in these processes is played by hydrocarbons and their transformations. On the other hand, hydrocarbons emitted with the exhaust of vehicles are the source of a vast range of organic substances. Under the smog conditions free radicals, phenols, peroxides, aldehydes, ketones, carboxylic acids and other substances are formed from hydrocarbons, which largely determine the biological effect of the photochemical smog. The free radicals are capable of reacting with nitrogen oxides, forming nitrates and with ozone forming peroxides and ozonides – the substances whose physiological activity is particularly high.

Air pollution in photochemical smog conditions may adversely affect:

1. human well-being and health;
2. materials and products;
3. plants and animals;
4. atmospheric composition and the processes therein.

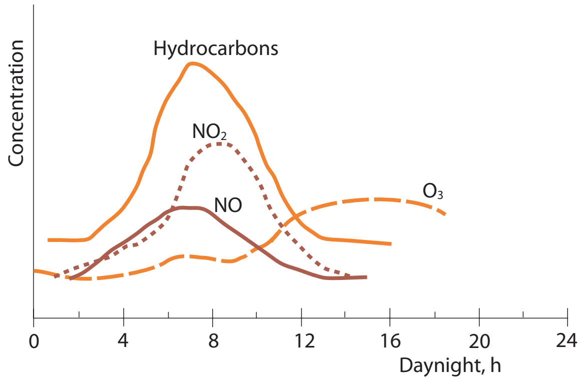


Figure 7.26. National report on use of natural resources in Republis of Uzbekistan 2008

First of all, the harmful effect of ozone must be noted, which is determined by the fact that ozone is a powerful oxidizer. Thus, it causes irritation, can trigger asthma and affect lung function. The maximum permissible concentration level of ozone set in USA is 0.1 cm^3/m^3. Ozone is able to accelerate the deterioration processes of polymer materials and rubber. The negative effect of increased ozone concentration on plants has also been proven, for example, in California it inflicts a real material damage.

Another group of substances with the most evident physiological effect are peroxides and nitrites, especially peroxyacetyl nitrates. These substances are characterized by high toxicity and irritant effect (they cause eye watering).

In contrast to the photochemical smog, the London-type smog is formed in humid air, especially if there is a limited dispersion of pollutants (inversion conditions) and, above all, it is determined by sulfur dioxide, carbon monoxide and aerosol influence. Entering into the humid air atmosphere, sulfur dioxide dissolves in fog droplets creating inhalable aerosols, which, unlike sulfur dioxide, are not absorbed in the upper respiratory tract and mucous membranes of the nose, but enter the lungs.

In alveoli the sulfur dioxide sorbed in aerosol particles is desorbed, causing irritation that can lead to impaired lung function, aggravating the course of chronic diseases. It should be noted that during the London-type smog the content of nitrogen oxides and carbon oxides also simultaneously increase in the air, and changes take place in the composition of airborne aerosols, i.e., the aerosols formed due to the incomplete combustion of fossil fuel become dominant. However, not only SO_2 but also nitrogen oxides and hydrocarbons are sorbed on such sprays. Upon aerosol inhalation these substances can desorb into the lungs and enter the circulatory and lymphatic system, affecting the functions of the heart rate and other organs. During the London smog the growing concentration of pollutants in the air can increase human mortality and acute exacerbation of diseases, as it was recorded in London, in December 1952 (Figure 7.27).

Figure 7.27. Air pollution effects on human health during the London smog in December 1952, London.

It should be noted however that the occurrence of the London-type smog in the developed world today is greatly reduced, taking into account the improved fuel combustion technologies, exhaust gas treatment and other air pollution control methods.

7.7. Acid precipitations

Sulfur and nitrogen oxide emission growth leads to the situation when, as they oxidize in the atmosphere, the respective acids are formed and the pH of precipitation may drop down even to pH ~2-3. The term 'acid rains' appeared as early as in 1872.

The increased entry of various acid-forming oxides (NO, NO_2, SO_2, SO_3) into the atmosphere causes an effect that the pH of precipitation may decrease, but at the same time the composition of atmospheric precipitation can be significantly altered.

Precipitation acidification is caused by photochemical oxidation of sulfur and nitrogen oxides in the atmosphere, the subsequent reaction with water vapour present in the atmosphere to form sulfuric acid, nitric acid and sulfurous acid, and the fall with the precipitation in the form of rain or snow. If rain water contains acid, its pH is lowered. Acidification of precipitation also causes the surface water acidification.

A significant volume of gases, which may cause acidification of atmospheric precipitation, is generated in the industrialized countries (Figure 7.28). As such precipitation falls, it may affect the overground water, soil and vegetation. Pure water has a pH of ~5.7, determined by atmospheric carbon dioxide dissolution and formation of weak acid – carbonic acid. Due to the impact on the atmosphere of sea salt aerosols, as well as the aerosols generated by soil erosion, the atmospheric precipitation pH may increase even up to a pH value 8. However, as a result of industrial contamination the acid rain may be typically formed with a pH of less than 5.6.

Precipitation in the form of rain and snow is created in the upper layers of the troposphere by condensation of water evaporating from the continent, ocean and sea surfaces. Initially, the water vapour reaching the atmosphere condenses to form water droplets or ice crystals. Condensation takes place around condensation centres, which typically can be aerosol particles. At the same time, the substances that exist in the condensation centre affect rain and snow water content. Another important factor influencing the composition of atmospheric precipitation is the gases in the atmosphere, which have the capacity to dissolve in water. As a result of anthropogenic contamination the composition of atmospheric precipitation changes considerably. Acidification of precipitation typically manifests itself not only as a pH decrease, but also as a change of the relation between the different ions and sulfate content increase. However, the most typical anthropogenic pollution influence on the composition of precipitation takes the form of acidification.

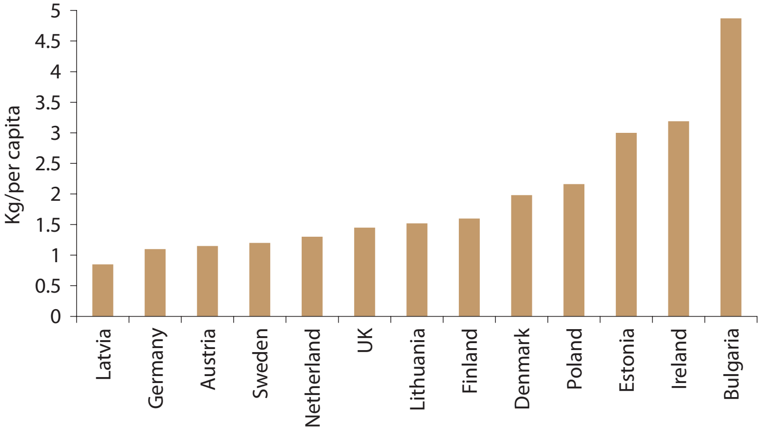


Figure 7.28. Emission rates of gases causing atmospheric acidification in the European countries (2004)

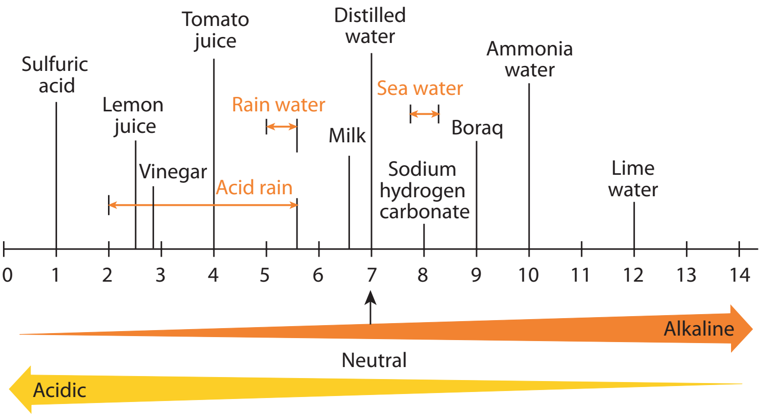


Figure 7.29. pH reaction indicators for different solutions

It should be noted that acidification of precipitation is not observed in Latvia. In some regions as a result of cement and building material production significant amounts of alkaline dust and aerosols are released into the atmosphere, therefore the precipitation becomes alkaline. The analysed concentrations of substances and their modules of fall in precipitation elsewhere in Latvia also do not show significant local pollution sources or the impact of cross-border pollution.

Today a question of water acidification is still topical, and it is caused by the changes in atmospheric precipitation pH level.

In natural water reservoirs several stages of acidification can be distinguished. In the first phase, the inflow of acidic water leaves the average pH largely unaffected. This is due to some natural water buffering capacity, which determines the presence of carbonates in the water. In the first phase of the acidification process the hydrogen ions neutralize hydrogen carbonate ions.

If water alkalinity goes below 0.1 mol/l, the natural water buffering capacity is exhausted. In such reservoirs at the period of intense acidic water inflow (in autumn, but especially in the spring during snow melt) a rapid pH drop is possible. These processes to some extent can be offset by the increased dissolution of alkaline rock. It is necessary to note that even a short-term decrease in the pH of water leads to serious ecological consequences. Of particular note is the impact of acidification on benthic organisms, fish eggs and other aquatic organisms in their early stages of development.

As the acidification processes continue, the water pH is settled below 5.5. Such a body of water is denoted as moderately acidic. At this acidification stage of the body of water substantial changes in its ecosystem take place.

The concluding stage of freshwater acidification is characterized by formation of a stable pH (pH <4.5), which persists even when the atmospheric precipitation acidity is lower. This effect can be explained by the presence of humic substances, magnesium and aluminium compounds in water. In general, these substances, either by connecting or separating the protons, stabilize the pH value.

At the reduced water pH the intensity of chemical processes with aluminium participation increases. Naturally the aluminium concentrations in water reservoirs are low, but insoluble aluminium compounds – alumosilicates, which are the main components of clay, make up a large part of the sediments in water bodies. As the acidity of the water reservoir increases, the intensive dissolution process of these compounds takes place, and as a result the aluminium compounds enter the water. Recently it has been proved that aluminium is one of the key factors determining the toxic effects of environmental acidification.

Atmospheric acidification also directly affects various materials used in building, but primarily those containing carbonates. Materials containing limestone le in acidic conditions dissolve (become weathered).

The harmful substances damage plants primarily at the molecular level, and only after the changes at this level the overall impact on metabolism process begins, affecting the entire organism. Sulfur dioxide has an essential influence on plant development. Sulfur dioxide released into the plante first of all impacts the cells, which regulate the plant's gas exchange with the environment. Even a minor amount stimulates inflow channels in the gas stomata of leaves and they remain constantly open. Once in the plant cells, the molecules of sulfur dioxide (in the form of sulfite ion) easily pass through the cell membrane. Subsequently they affect mitochondria and chloroplasts. These effects reduce the intensity of photosynthesis process. In addition, SO_2, SO_4^{2-} and other sulfur dioxide transformation products interact actively with enzymes within the cell, affecting such processes as, for example, the ATP synthase in mitochondria, –S–S– link splitting in enzymes, etc. The following visual changes quite often occur in plants due to the activity of the plants' natural enemies – a variety of micro-organisms.

Figure 7.30. Forest destruction due to acid precipitation exposure, USA, state of Maine

Different plant species have a different sensitivity to pollutants. The pollution caused by sulfur dioxide particularly impacts lucerne, wheat, yews, pines, while apricots, gladiolus, peaches, etc. are sensitive to the pollution with fluorine compounds. The impact of a specific air pollutant cause different symptoms in various plant species. Atmospheric acidification typically results in destruction of coniferous trees (Figure 7.30). If a few decades ago the forest drying due to acid precipitation was a major problem in Central Europe and Scandinavia, today this type of impact is observed in China, India, and the United States.

The air pollution effects on inorganic materials have long been observed. The description of exposure to the London's atmosphere dates more than 300 years back: «Contaminated air coats literally everything with a thick layer of soot. Causes rusting of crockery and corrodes even steel beams and the most durable stone.»

Given the amount of pollution today, the effects of pollutants on inorganic materials are specifically investigated. Atmospheric pollution with sulfur and nitrogen oxides has the most important impact on inorganic materials. Iron, cast iron and steel corrosion takes place in parallel with a variety of electrochemical processes, which are initiated by micro-alloys in the metal products themselves and also by aerosol and dust particles accumulated on the metal surface. The main role in the course of this process is played by sulfuric acid and sulfates resulting from SO_2 oxidation.

In case of non-ferrous metals the air pollution by sulfur dioxide causes direct corrosion of surface layer.

Figure 7.31. Weathering of a lion figure (Athens, Greece) due to acid rain exposure

The influence of air pollution on architectural monuments is particularly disastrous (Figure 7.31). Extensive research has been conducted in Italy, France and Germany to protect from air pollution exposure the sculptures placed in open air.

7.8. Indoor air pollutants

When conducting the analysis of air pollution, the air quality outdoors is usually analysed. At the same time, people's health can be significantly more affected by air pollution on their living and working premises (Figure 7.32).

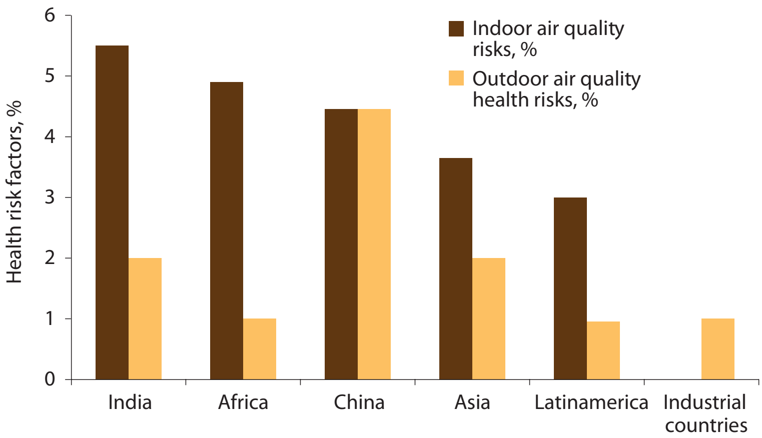


Figure 7.32. Relative impact of indoor and outdoor air pollution (the share of risk factors) on human health in different regions of the world

This is determined by several factors, of which the first to be mentioned is the air pollution in human living environment, caused by the external air supply. An example of such a situation can be the elevated lead and polyaromatic hydrocarbon content in the dwelling houses near a highway. Serious indoor air pollution can be caused by a variety of local sources – kitchens, ovens, as well as furniture, polymeric materials, painted surfaces, animals. The level of environmental pollution with one or another substance is also affected by the ventilation of rooms. Its intensity must be balanced against the need to maintain an optimum temperature regime in living quarters.

Creation of new materials and substances result in the human living environment receiving increased quantities of new substances, and thereby being contaminated. For example, new insulation materials, cleaning products, cosmetics formulations, solvents, plant protection products cause human contact with substances having proven toxic properties. The human environment pollution can cause a variety of consequences, including immediate death. There are cases of death due to poisoning by carbon monoxide gas from the stoves and fireplaces. Even in developed countries, the indoor pollution may be a cause of death, as evidenced by the deaths as a result of legionellosis.

Significantly more widespread and important is the long-term effect of living environment pollution on human health.

However, this effect can become evident after a considerable time, even decades later, and therefore, using modern research methods (especially results of epidemiological studies) the harmful effects of substances are difficult to prove. Substances which are characterized by this type of impact include radon, asbestos, formaldehyde and others. However, the air pollution in the people's homes and workplaces today is considered to be one of the most important causes of some diseases, such as lung cancer.

A particular emphasis should be placed on the allergic influence of indoor air pollution, which may result, for example, in asthma.

Air pollution can be caused by both organic and inorganic materials, as well as micro-organisms (Table 7.8).

Table 7.8. Typical contaminants in the environment of human life

Pollutant	*Source of substance*
Formaldehyde	Particle board (chipboard), smoking, heat insulation materials
NO_2	Natural gas heating
CO	Stoves, car exhaust fumes
Polyaromatic hydrocarbons	Wood, coal, gasoline combustion
SO_2	Combustion of fuels
Cl_2	Bleaches, chlorinated water
Evaporable organic substances	Paints, household chemicals, polymers
Dust and aerosols	Combustion of fuels, food preparation, heat insulation materials, carpets, smoking
Microorganisms, viruses	The development of mould, pets
Radon	Buildings, soil, water

Typical living organisms, which determine biological contamination, are:
- microscopic animal, feather, skin, hair particles. Dust and other mites as well as their particles;
- metabolism products of living organisms (sweat, fecal matter particles);
- fungi, bacteria and viruses;
- pollen.

A significant group of environmental pollutants are living organisms. They can be a source of air pollution, a cause of disease, and they can also damage materials used in living environment. Pollutants of biological origin and living organisms may be transported by air currents, they are invisible and often quite difficult to determine.

Living organisms that determine biological contamination can cause:
- allergic reactions;
- infectious diseases;
- poisoning with toxins.

Clearly, in any room inhabited by people some of these pollutants will be found. Often it is the presence of nutrients and moisture that triggers the development of biological contamination.

Allergic reactions cause common human health problems and these can be instigated by animal hair fragments (such as dog and cat hair), as well as by dust mites, fungi and their spores, and pollen. According to their consequences, allergic reactions vary from mild discomfort to life-threatening asthma attacks.

Figure 7.33. Dust mite

A typical infectious disease caused by indoor air pollution by microorganisms is legionellosis. 'Legionnaires' disease' is caused by the bacterium *Legionella pneumophila*, which is one of more than 20 similar bacteria that cause the disease referred to as legionellosis. Legionellosis outbreaks have been observed in the U.S. as well as in other countries, and, given the high lethality of the disease, it has been studied quite extensively. Legionellosis is a lung disease caused by environmental pollution (it does not spread from human to human) with *Legionella* bacteria. These bacteria can multiply in water, in closed water circulation systems, ponds, air-conditioning systems and in water spray (showers, stoves, garden watering equipment, etc.), and be inhaled in a form of aerosols. The bacteria as aerosols can be transmitted even to relatively large distances.

To protect oneself against legionellosis it is important to properly set up and operate the water circulation systems. In practice, this means the need to prevent the opportunities for bacterial multiplication.

Also, the allergic alveolitis can be caused by airborne micro-organisms. The acute form of alveolitis becomes manifest 6-8 hours after exposure as 'acute respiratory infection', fever, shortness of breath, cough and muscle aches. If the contact with the cause of illness is interrupted, it may last a few days. The chronic form of the disease is more common when there is a constant low-level source of pollution, such as pets. This condition is caused by *Micropolyspora faeoni*, *Cytophaga allerginae*, *Aspergillus fumigatus* and other fungi, which, for instance, also cause the allergy to the hay, particularly, if the hay is mouldy. The same microorganisms may develop in air conditioning and ventilation equipment.

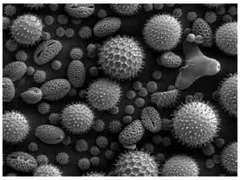


Figure 7.34. Pollen of higher vegetation

Fungi, bacteria and other microorganisms present in the indoor air can also cause diseases such as asthma, allergic rhinitis (caused by *Dermatophagoides pteronyssinus*) and, for example, the 'sick building syndrome'. The sick building syndrome is expressed as a host of different symptoms when living or working in certain rooms and stops on leaving the premises. Typical of this syndrome is the inflammation and watering of the eyes, runny nose, headache, irritability, difficult breathing, and sometimes asthma. Air conditioning and humidification systems can also cause infectious diseases. The sick building syndrome can be detected both in newly-built, technically well-equipped buildings as well as old, worn-out houses. The sick building syndrome may be caused by the substances resulting from fuel combustion, substances and materials used in building construction or in the work process, biological air polluting materials (quite often the effect is increased by inadequate ventilation).

Toxic substances (toxins) produced by living organisms may be another cause of health problems. The toxins produced by living organisms can cause damage to certain organs and tissue, but they can also affect the immune system and the nervous system.

Figure 7.35. Fibres of asbestos

In the developed countries, people spend indoors up to 70% of their time, therefore the air quality there should be given special attention. A variety of inorganic materials can contribute to the overall pollution level. If NO_2 in rural and clean urban air is 0.01-0.02 mg/m^3, in the living rooms with gas heating in the kitchen, it may be 0.07 to 0.15 mg/m^3, but in the tobacco smoke-filled rooms up to 1.2 mg/m^3. Increased nitrogen oxide content can affect children's health, increasing the risk of respiratory diseases. For example, it has been proved that the raise of NO_2 concentration by 15% indoors increases the number of respiratory disease cases in children by 40%.

The consequences of urban air pollution by asbestos have been widely studied and the detrimental effect on human health is proved. However, the artificially-produced fibrous materials (glass wool, glass fibre, rock wool) can also lead to similar contamination, especially when aging. Another topical factor may be the indoor air pollution with substances that are typical of outdoor air pollution cases: sulfur oxides, heavy metals, aerosols, etc.

Bibliography

Aulika B., Avota M., Baķe M. Ā., Dundurs J., Eglīte M., Jēkabsone I., Sprūdža D., Vanadziņš I. (2008) Vides veselība. Rīga: RSU.

Baird C., Cann M. (2005) Environmental chemistry. N.Y.: W. H. Freement and Company.

Berner E. K., Berner R. A. (1996) Global environment. Upper Saddle River: Prentice-Hall Inc.

O'Hare G., Sweeney J., Wilby R. (2005) Weather, climate and climate change. London: Pearson Education Ltd.

Hill M. K. (1997) Understanding environmental pollution. Cambridge: Cambridge University Press.

Jacobson M. Z. (2002) Atmospheric pollution: history, science and regulation. Cambridge: Cambridge University Press.

Principles of environmental chemistry (2007) (Ed. R. M. Harrison) Cambridge: RSC Publishing.

Van Loon G. W., Duffy S. J. (2008) Environmental chemistry: a global perspective. Oxford: Oxford University Press.

Weiner R. F., Matthews R. (2003) Environmental engineering. Amsterdam: Elsevier.

Williams I. (2005) Environmental chemistry. Chichester: J. Wiley.

Indoor and outdoor air pollution. Accessible: w*ww.lbl.gov/Education/ELSI/pollution-main.html*.
Air pollution. Accessible: *www.nlm.nih.gov/medlineplus/airpollution.html*.
Air quality in EU. Accessible: *ec.europa.eu/environment/air/index_en.htm*.
Air pollution. Accessible: *www.eea.europa.eu/themes/air.*
Air quality in Europe. Accessible: *www.airqualitynow.eu/*.
Air pollutants. Accessible: *www.epa.gov/ebtpages/airairpollutants.html*.

8. WATER POLLUTION

Natural composition and properties of water vary due to different geographical, geological, biological and other reasons. These are natural changes and their significance may be quite substantial, for example, during the floods the river water composition may differ from the summer low-water period water quality indicators ten or even more times. Human activity can influence water quality significantly more than the natural causes. For example, the human impact on the natural waters may disrupt their hydrological regime (river flow rates, affect the lake level), or to change the composition of the waters by pollution. Anthropogenic impacts disrupt the water and substance cycles and affect aquatic ecosystems. Contamination of water with pathogenic (disease-causing) microorganisms, heavy metals, pesticides, and water eutrophication are considered to be of crucial importance (Figure 8.1).

Pollution denotes a change of a certain water characteristic or a set of characteristics, which makes it difficult or even precludes the use of water for a specific purpose. From the nature conservation point of view this is not relevant, because the economic usefulness is not an indicator of natural wealth and diversity or of the environment quality. However, environment protection often has to be balanced with economic priorities, and therefore the inadequacy of water quality for certain uses is called water pollution.

The waters are polluted, if substances or physical conditions have changed the water composition and properties to such an extent that the functioning of its ecosystems is affected, or the water use for specific purposes is restricted. Water pollution can also be caused by such changes in water composition, in the result of which the substance content present in the water substantially differ from that which existed before. However, is it is not always possible to determine this initial water quality in the areas that have been populated for a long time

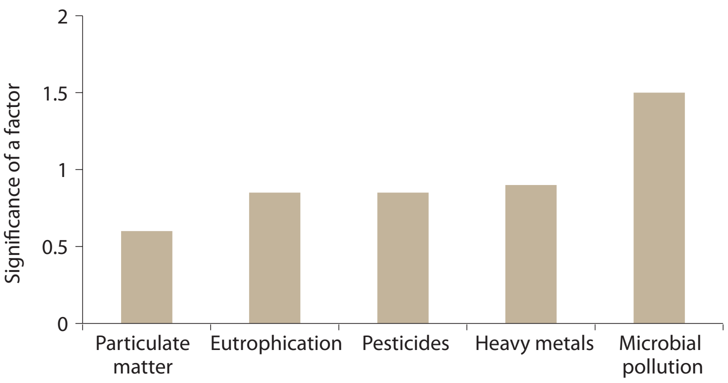


Figure 8.1. Rating of global water pollution (0 – water quality is not affected; 1 – the waters are polluted, but using appropriate protective measures, they can be used; 2 – water pollution can cause significant risk to human health)

Chemical pollution is caused by entry or presence of chemicals in the waters and, depending on the pollutant characteristics, one can distinguish between the contamination with inorganic substances (biogenic elements, inorganic salts, toxic trace elements, radionuclides) and organic substances (biologically readily degradable substances, oil products, pesticides, surfactants and other substances). Physical pollution is caused by physical effects such as the influence of temperature on the water, but biological contamination is created by the entry of living organisms atypical to the particular type of water, such as viruses, bacteria.

According to its source, water can be classified as follows:

- surface water (rivers, lakes, seas, oceans);
- underground water, spring water;
- precipitation water (rain, snow, ice water, dew, fog);
- waste water.

This division is conditional, because the water is in constant motion during the cycle (hydrologic cycle) and therefore any classification reflects only a certain part of the cycle, in which the particular amount of water currently happens to be. For example, the spring water is underground water, but coming to the surface, it becomes surface water. The river water also changes its composition and properties when falling into the seas or oceans, but the ocean mist is often salty to taste, and its properties are different from the fog, for example, in tropical forests after the rain.

Water features and content may change not only due to pollution but also to cleaning. In nature, water has a self-cleaning ability and it is an essential condition, because of which the water can be called a renewable resource.

The existing water treatment technologies allow purifying the water, rendering it usable for a particular sphere of its use. Depending on the type of contamination, it can be categorized into the chemical, physical and biological contamination.

Two types of water pollution sources can be distinguished:

1) point sources of pollution;
2) diffuse pollution sources.

Typical water pollution point sources are:

1) pipes through which either treated or untreated sewage water of the cities or factories is discharged into water reservoirs, rivers, lakes and seas;
2) agricultural effluents;
3) oil and petroleum product spill from pipelines.

Diffuse pollution sources are scattered and it is more difficult to identify and assess them. The main diffuse sources of pollution are:

1) surface runoff from agricultural lands, construction areas, burned forests;
2) surface runoff from agricultural lands, which are contaminated with chemical fertilizers, natural fertilizers (biogenic element runoff), pesticides or saline waters;
3) rainwater runoff from urbanized areas;
4) drainage from abandoned or operational mines, quarries;
5) fall of substances with precipitation (sulfur, nitrogen and metal compounds, organochlorine compounds);
6) leaks from dumping-grounds and landfills into underground and surface waters.

Diffuse water pollution is generally more dangerous than point source pollution. For example, the major part of nitrogen and almost half the amount of phosphorus compounds contamination in the Baltic Sea is caused by the diffuse pollution (Figure 8.2).

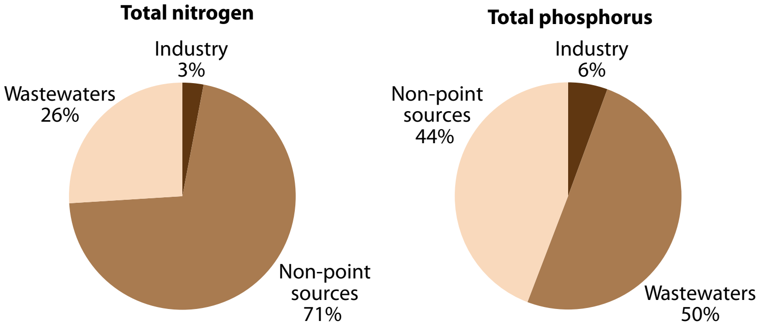


Figure 8.2. The sources of the pollution with nitrogen and phosphorus compounds in the Baltic Sea, 2000

Every type of pollution is characterized by certain specific features, but largely the borders between the effects of pollutants converge. Municipal wastewaters are more likely to have an increased content of various chemicals, but the industrial effluents bring the ever-increasing quantities of biogenic elements into the environment. It should be noted that the waste water of specific industries is characterized by a rather strictly determined spectrum of specific substances, such as the textile industry, polymer processing, chemical industry.

Water contamination with organic substances always has a very complex and intricate character. Organic pollutants are able to actively interact with a variety of naturally-occurring substance groups. Another special feature of this group of substances is that they are actively transformed or destroyed by a variety of living organisms, primarily bacteria.

Among the groups of substances which have recently been the focus of particular attention, the following should be noted:

1) plant protection products (herbicides, insecticides);
2) surfactants;
3) petroleum products;
4) phenols;
5) stable organic substances;
6) toxic trace elements and heavy metals;
7) carbohydrates, proteins, aminoacids.

The pollution of natural waters by oil or petroleum products is particularly dangerous.

Synthetic detergents contain a variety of substances that may pollute the aquatic environment:
1. surfactants such as sodium dodecyl sulfate;
2. bleaching agents – usually various oxidizing agents such as sodium perborate;
3. enzymes such as lipase;
4. corrosion inhibitors such as sodium silicate;
5. fragrances;
6. inert material (fillers) such as sodium sulfate;
7. stabilizers, such as magnesium silicate.

Surfactants are a group of water-soluble organic substances that concentrate on the surfaces and reduce the water surface tension.

Today, the question regarding the water environment pollution with synthetic detergents has gained topicality.

From the environmental point of view, the environment quality may be most affected by two components of synthetic detergents:

1) surfactants;
2) water softeners.

The substantial contamination of the environment (air, water, soil, underground environment) is the pollution with substances characterized by high stability. Among these persistent organic pollutants (POPs) occupy a special place. Due to the in-depth research of these substances and recognition of hazards associated with them, as well as the amounts of their production and their toxicity, the use of several POPs is limited by legal acts, among which the first to be mentioned is the Stockholm Convention, aimed at protecting human health and the environment from POPs, restricting the use of substances that are characterized by high toxicity and persistence in the environment, providing a safe and permanent disposal of these substances and reducing uncontrolled emissions of POPs into the environment. According to the source and application, POPs can be divided into 3 groups:

a) POP-containing plant protection products (aldrin, DDT, dieldrin, endrin, hexachlorobenzene, heptachlor, chlordane, mirex, toxaphene);
b) POP – containing chemical products for industrial use (hexachlorobenzene, polychlorinated biphenyls);
c) POP – containing by-products (polychlorinated dibenzo-p-dioxins, polychlorinated dibenzofurans, polyaromatic hydrocarbons). POPs are characterized by high persistence in the environment and a high potential for bioaccumulation.

8.1. Water resources and their use

Water is a renewable natural resource and a pre-requisite for life on the Earth, and it is the most important food product for humans and many other species. Fresh water is only a small part of the terrestrial water – about 3%. Much of the fresh water (a little more than two-thirds) comes from glaciers and snow, while one-third – is the underground water, because rivers and lakes make up only a very small part of the fresh water.

The formation of natural water sources is influenced by the hydrological cycle, which can be divided into five major parts: the waters of the oceans, atmosphere, glaciers, underground, and fresh water resources. Hydrological cycle shows the interrelation among these key water sources and reflects the great role of evaporation and precipitation fall processes in formation of the water balance. The major energy factor which determines the participation of water in the global water cycle is the solar radiation causing the mass of water on the Earth surface to heat up and evaporate. Water does not evaporate solely from the surface of the seas and oceans, – the soil moisture, glaciers and the snow cover of the Earth evaporate, too. Water circulation time for different elements of the hydrological cycle is different: for atmospheric water it is 10 days, 12 days for the water in rivers, in lakes – 7 years, the active exchange zones of underground water (groundwater) – 200-300 years, the water in the oceans – 3000 years, artesian groundwater – 5000 years, water hidden in continental glaciers – 8000 years. These parameters allow to estimate, how much water participates in a overall cycle per year – these are only 0.03% of the total amount of water, but all the water on the Earth makes a complete cycle only in about 3000 years.

Although the fresh water supply is significant, not all the surface and underground water can be used for human economic activities. Regarding the number of global population from the perspective of separate continents, these values can be reflected as available freshwater amounts per capita (Table 8.1).

Table 8.1. Fresh water available for economic activities, 2005

Continents	*Population, millions*	*Available amount of freshwater in the form of ice, km³/per capita*	*Available freshwater in bodies of water, km³/per capita*	*Available underground freshwater km³/ per capita*
North America	332	271.08	81.33	12 951.81
South America	378	2.38	9.08	7936.51
Europe	732	24.89	3.45	2185.79
Africa	924	0.0002	34.39	5952.38
Asia	3968	15.37	7.72	1965.73
Australia and Oceania	34	5.29	6.50	3529.41

The World Health Organization in its recommendations indicates that for a contemporary healthy life style of humans it is necessary to have access to more than 1700 m^3 of fresh water per capita per year.

Water consumption, as shown in the example of drinking water in the world today, differs significantly in various parts of the world. In economically developed countries the average per capita consumption reaches 500-800 litres per day (300 m^3 per year), while in most developing countries it does not exceed 60-150 litres per day (20 m^3 per year). There are also significant differences between water consumption in large cities (300-600 litres per capita per day) and small towns (100-150 litres per capita per day). In the developing countries of Asia, Africa and South America water supply in settlements reaches an average of 50-100 litres per capita per day, but in very large areas only 20-60 litres of water per capita are available per day.

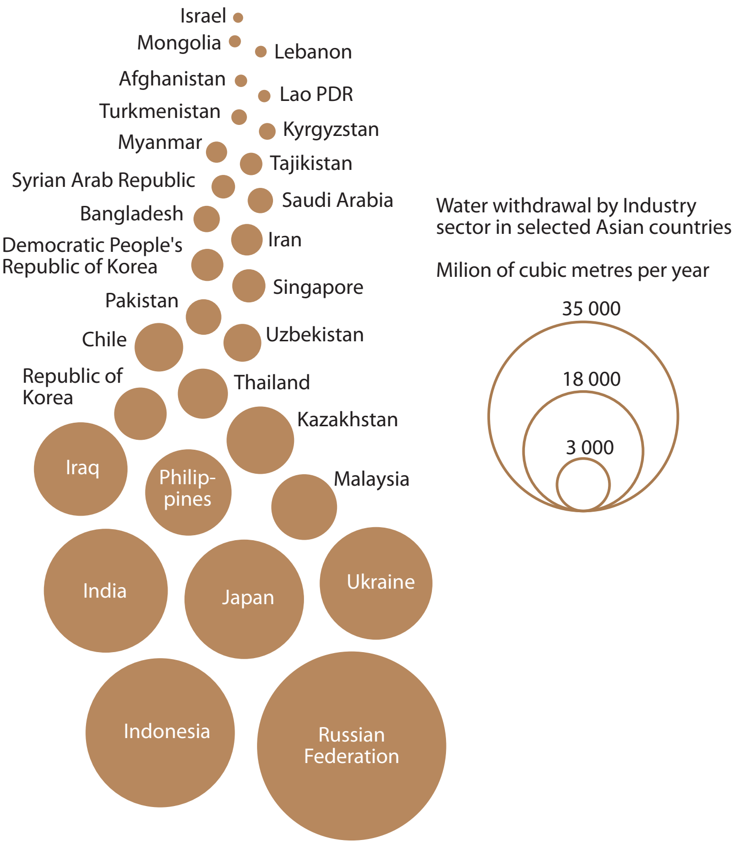


Figure 8.3. Water withdrawal by industry in Asian countries (millions of m^3/year) (Riccardo Pravettoni, GRID-Arendal)

However, already in the 2005 more than 30 countries, whose inhabitants make up 8% of the world's population, experienced chronic fresh water shortage and this process will intensify in the future. The main water consumption sectors may differ quite considerably in the countries around the world, depending on the nature of their economy. There is a reason to believe that in the near future the water consumption will increase mostly for agricultural purposes.

The lack of available freshwater causes suffering to the wildlife in all its different varieties, and to people. Although the cases where people's deaths are due to water shortage are very rare and they are a result of a particular accident, a natural disaster or an ill-considered action, the inadequate supply of clean water to the households causes spreading of a large number of diseases. Due to such characteristic diseases as diarrhoea, malaria and parasite-caused diseases up to 500 million people suffer annually and more than 3 million people die, the majority of them being children and adolescents.

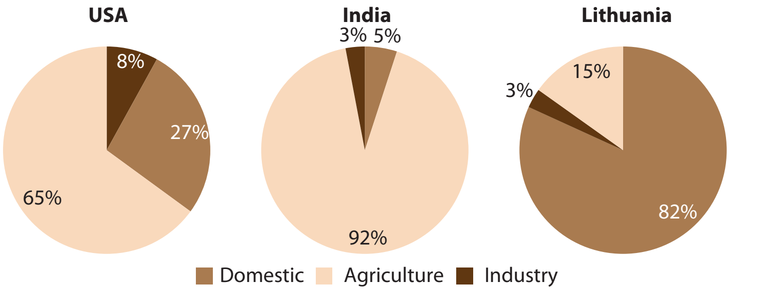


Figure 8.4. The use of water resources depending on the national economy – the U.S.A, India and Lithuania

Although the Baltic States and Latvia in particular are among the best provided with underground water resources in the world, nevertheless, also in these countries the conservation and efficient use of the water resources is just as important as in the rest of the world.

8.2. Natural water composition and conditions of formation

The formation of the natural water sources is complex and it is influenced by a number of factors, among which the conditions of physical geography and geology are of particular importance (such as the relief, climate, rock formation and weathering, soil cover, vegetation). The composition of water also depends on the environment, in which it is located; it is different in seas and oceans, rain, underground and on the surface. It should be noted that the water composition and properties vary depending on the external conditions and that the natural variability of the water content is due to the ability of the substances forming the lithosphere and atmosphere to dissolve in water. Today the composition of water can be very significantly influenced by the human economic activities.

Site-specific relief indirectly affects the water composition. The relief primarily affects water change regime – surface and underground runoff, distribution of precipitation. The relief of the place also affects the migration of salts in the soils, their bogging trends, which in turn affect the water content. The climate influences the water composition by weather conditions, and the main factors here are the amount of precipitation, temperature and water evaporation regime. Since the mineralization of atmospheric precipitation is lower than the surface water mineralization, great amounts of precipitation may decrease it. On the other hand, as a result of the cross-border transfer of air masses, particularly in modern times, the substances in air masses can affect the composition of precipitation. The development of 'acid rain' takes place in this manner, and this type of process is largely responsible for the environmental contamination with persistent pollutants – mercury, organo-chlorine substances.

Another set of factors affecting the chemical composition of water is related to the solubility changes of various salts due to temperature changes and other processes which determine the amount and form of dissolved substances. The regional climate significantly influences such a factor of water composition formation as evaporation. Rock weathering also has an important role in the formation process of water content.

Minerals and rocks are formed and disintegrated (weathered) as a result of exposure to physical (mechanical), chemical and biological factors. The rock weathering is determined by the fact that the minerals formed in high-temperature and pressure conditions, can be unstable in contact with water, especially if it is saturated with carbon dioxide and oxygen. Chemical weathering of rocks is caused by the impact of natural waters and carbon dioxide gas, salts and organic substances dissolved therein. This reaction is based on the oxidation or reduction, which occurs with mineral-bound substances, their hydrolysis, dissolution, ion hydration and transformation in such particles, which are found in natural waters. Chemical weathering predominantly takes place with active participation of either carbon dioxide (carbonates), sulfates or water organic substances. Rock weathering is one of the key factors significantly affecting the mineral composition of natural waters. Today, for example, the aluminum content levels in natural waters are increased by intense weathering of aluminosilicate under the impact of acid rain.

Minerals are naturally occurring inorganic compounds, which have a crystalline structure and a particular chemical composition. Rocks are stable geological bodies that are composed of mineral aggregates. The rocks make up the Earth's crust. According to the origin, the rocks are classified as magmatic, sedimentary or metamorphic.

Igneous rocks are formed of magma, as it cools and hardens in the depths of the Earth (intrusive magmatic rock) or flowing out to the surface of the Earth in the form of volcanic lava (effusive rock). Metamorphic rocks are formed from magmatic rocks and sedimentary rocks, as well as older metamorphic rocks in metamorphism processes. Metamorphism is a set of geological and geochemical processes, in which under the exposure of high temperature, pressure and chemically active solutions and gases, the changes in rock mineralogical composition and structure take place. The major sedimentary rocks are clay, conglomerate rocks (sandstone, breccia, conglomerates) and carbonate rocks. Clayey rocks predominantly consist of silicates and aluminosilicates, but for their composition potassium, magnesium and iron compounds are of great importance.

Carbonate rocks consist of magnesium and calcium carbonates. Water composition is formed as minerals and rocks dissolve in aquatic environment, or as a result of their chemical transformation. The main minerals whose weathering affects the composition of natural waters are the rock salt (NaCl), gypsum ($CaSO_4 \cdot 2H_2O$), calcite ($CaCO_3$), dolomite ($CaMg(CO_3)_2$), siderite ($FeCO_3$), goethite (FeOOH), quartz (SiO_2) and aluminosilicates.

The composition of natural waters, is very significantly affected by the leaching of substances from the soil. This effect can manifest itself in two ways:

1. by changing the chemical composition of water that percolates through the soil;
2. by impacting the groundwater chemical composition.

There is a distinction between complete and partial dissolution of the rocks. As a result of complete dissolution a mineral is fully dissolved, forming only water-soluble substances. Partial dissolution results in water-soluble substances and a new mineral. The main groups of substances affecting mineral dissolution, are acids dissolved in water (carbonic acid, sulfuric acid, hydrogen sulphide, organic acids, humic acids), gases. Mineral stability (resistance to weathering) greatly differs. This means that in the soil, which is a mixture of several minerals, some of these will dissolve significantly faster than the others. Based on the way they affect the natural water content, the most important of mineral weathering processes is the silicate and carbonate weathering.

The intensity of each of these processes is determined by the soil type and composition. Soils rich in organic matter (humus), especially in swampy areas, first of all enrich the waters with humic substances. Black earth, but especially clay (loam, clay, loess) soils promote ion composition changes in natural waters. It should be noted that the interaction of waters with the mineral substances existing in soil takes place with an active participation of CO_2.

The biological factors also influence the formation of water composition. It is particularly associated with activity of microorganisms. A set of biological factors determines the biological-biogenic transformation of natural waters, which, in turn, affects the microelements and determines the content of organic substances. Microorganisms are found even in groundwater up to 1000 m deep, and can grow at temperatures from 0 to 90 °C. The presence of microorganisms fundamentally affects the gas regime and determines the synthesis, dissolution and transformation of organic substances. The presence of microorganisms is the main determinant in the degradation processes of environmental pollutants and toxic substances. Water quality and composition is actively influenced by plants and animals.

The final stage in creating the water quality is completed by various water mixing processes, which may change the composition of water, for example, in case of poorly soluble salt formation. When the waters of various content mix, deposition of the dissolved or suspended substances is typical.

Since the water solubility of many substances is very high, the content of different dissolved substances in natural waters can vary significantly – from a few milligrams per litre up to tens or hundreds of grams per litre. Depending on the concentration of dissolved substances and ions, they are classified as dominant, macro components and microelements (Table 8.2).

Table 8.2. Classification of substances and ions dissolved in water, depending on their concentration

Concentration levels of substances dissolved in the water	*Characteristic ions and dissolved substances*
Predominant components (more than 5 mg/l)	HCO_3^-, Ca^{2+}, Mg^{2+}, Si, Na^+, Cl^-, SO_4^{2-}, CO_2, O_2, organic substances
Macro-components (concentration from 0.01 to 10 mg/l)	CO_3^{2-}, Fe, P, NH_4^+, NO_3^-, NO_2^-, K^+, F^-, H_2S
Microelements (concentration <0.01 mg/l)	Al, As, Ba, Be, Bi, Br, Cd, Ce, Cr, Co, Cu, Ga, Ge, Au, In, I, La, Pb, Li, Mn, Mo, Ni, Pt, Ra, Se, Ag, Sn, W, U, Zn

One of the most important characteristics of natural waters is a substantial variability of different inorganic ion concentration. If the waters of the seas and oceans are dominated by sulphate ions, in fresh water higher concentrations of hydrogen carbonate ions predominate.

8.3. Most significant water pollution problems

As a result of human activities the water is pervaded by substances different from those formed in natural processes, and they significantly affect water composition and properties. These are inorganic substances (biogenic elements, inorganic salts, toxic microelements, and radionuclides), organic substances (biologically readily degradable substances, petroleum products, pesticides, surfactants etc.) as well as physical impacts (Table 8.4).

Table 8.4. Groups of major water pollutants

Inorganic salts
Pesticides
Persistent organic compounds (e.g., polychlorinated biphenyls)
Radionuclides
Oil and its derivatives (such as diesel fuel)
Biogenic elements (e.g., nitrate ions, phosphate ions)
Surfactants
Metal compounds
Gases
Toxic inorganic substances (such as cyanide ions)
The heat (thermal pollution)
Pathogenic microorganisms

A significant source of water pollution is the use of chemical fertilizers in agriculture (Figure 8.5).

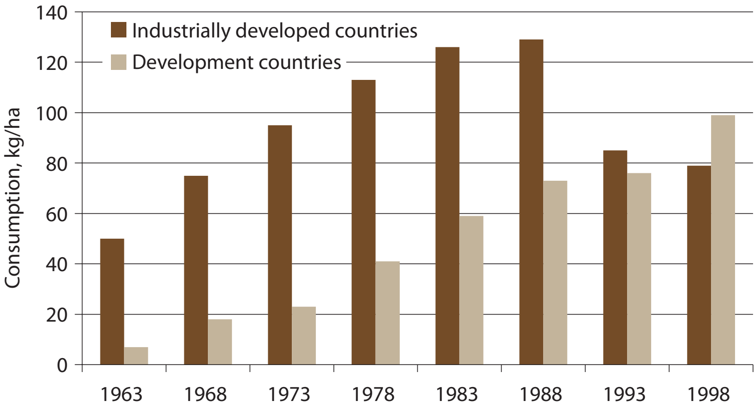


Figure 8.5. Changes of chemical fertilizer consumption trends in industrialized and developing countries

In Uzbekistan pollution of water with biogenic and organic substances is significant and widespread, while other types and elements of pollution are characteristic only of the local point pollution sources.

The term «biogenic elements» denotes the nutrients of living aquatic organisms – nitrogen compounds (inorganic ions NH_4^+, NO_2^-, NO_3^- and organic nitrogen compounds), phosphorus compounds (inorganic PO_4^{3-}, HPO_4^{2-}, $H_2PO_4^-$, polyphosphate ions and organic compounds) as well as iron and silicon compounds in their different oxidation levels and forms, taking into account their great importance in ensuring aquatic life processes.

Biogenic elements – nutrients whose presence is required for the development of living organisms.

Ammonia (ammonium ions) is formed in water reservoirs as a result of decomposition of organic nitrogenous substances. However, more often its content levels are determined by organic waste (slurry, sewage, excrements), household and industrial waste inflow into water bodies where nitrogen can be found in organic substances (proteins, amino acids, amines, nucleic acids). Decomposition of organic substances produces intermediates – relatively large quantity and variety of nitrogen compounds, however, their accumulation in water does not occur, as their biological stability is low. Depending on the pH of environment, the ammonia in water exists as NH_4^+ ion (if the water pH <7) or non-dissociated NH_4OH. If the pH reaction is alkaline, then the share of water-dissolved ammonia increases in the balance of this nitrogen compound form. Ammonium ions are toxic, especially for fish. Binding with organic or suspended substances reduces the bioavailability of ammonium ions. In natural waters ammonium ion content depends on the nature of biological processes therein and thus the concentration of ammonium ions is affected by the seasonal changes. Typically, in the summer season their intense assimilation takes place, whereas in winter their concentration in waters increases.

Nitrite ions (NO_2^-) are mainly formed as the intermediates of nitrogen compound transformation – the oxidation of NH_4^+ or reduction of NO_3^-. In uncontaminated waters the nitrite ions can be found in trace amounts (>0.001 mg/l NO_2^-) and the increase in their concentration is an important indicator of pollution.

Nitrate ions (NO_3^-) can be found practically in any waters. The clean surface water's nitrate concentration is generally 0.4 to 8 mg/l, but that of a contaminated water – up to 50 mg/l NO_3^-. The nature of seasonal variability of nitrate ions is similar to that of other biogenic elements. The character of nitrate seasonal variability is affected by the differences between their supply and consumption sources. The main sources of pollution are chemical fertilizers leaching from the soil, organic and inorganic chemical transformations and reactions. Pollution intensity influences the differences in nitrate ion concentration values in the river waters.

Nitrogen compound forms are interconnected and these compounds can change into one another. The nitrogen compound cycle is determined by microorganism activity. The key process in this cycle is the binding of nitrogen, which takes place in the course of photosynthesis (assimilation). Assimilation leads to formation of organic nitrogen compounds. As they decompose, the ammonia – ammonium salts – are formed (ammonification), which are subsequently converted into nitrates and nitrites (nitrification). Nitrification can also be defined as organic and inorganic nitrogen compound oxidation.

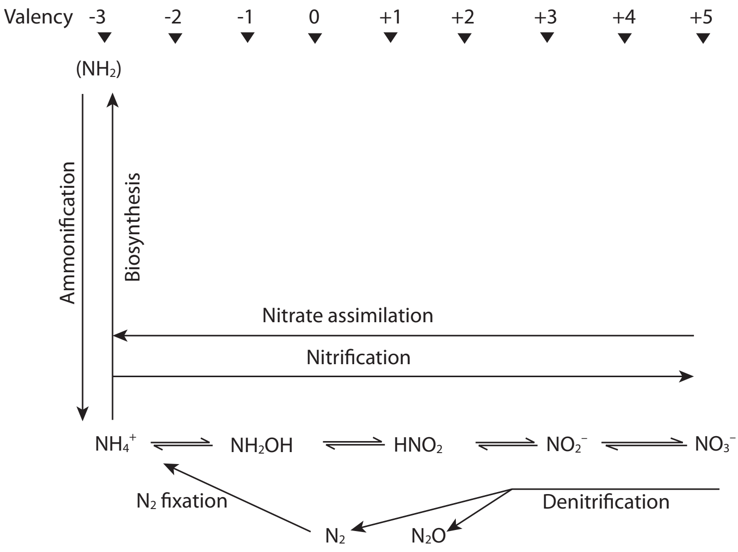


Figure 8.6. Reactions of nitrogen compound transformation in soil and water

The primary source of nitrogen compounds is atmospheric nitrogen fixation, which is performed by a few species of bacteria and in the nitrogen fixation reactions in blue-green algae. It is believed that the internal waters, depending on the intensity of the biological processes, the nitrogen fixation may form around 1 g N/m^2/year. Today, the biologically assimilable naturally bound nitrogen amount is comparable to industrially implemented nitrogen fixation, whose first stage is the synthesis of ammonia, which in turn is used as a source of synthesis of nitrogen fertilizers and other nitrogen compounds. Thus, the nitrogen compound source in waters is atmospheric precipitation, direct nitrogen assimilation and surface runoff. The nitrogen fixation occurs as a result of NO_3^- ions' reduction under the exposure to microorganisms (denitrification), under the formation of N_2, and the binding in the sediment. Nitrogen compound fall with the atmospheric precipitation determines their total balance.

The role of *Phosphorus* compounds in the ongoing reactions in the aquatic environment is determined by their function in hydrobiont metabolism and the fact that only relatively modest amounts of phosphorus are available in hydrosphere. Compared with the other elements required to be present for the development of living organisms (C, H, O, N, Fe, S), phosphorus is considerably less common and thus its limited availability often restricts the development of living organisms. In water phosphorus can be found in the form of many compounds. Increased amounts of *phosphate ions* ($H_2PO_4^-$, HPO_4^{2-}, PO_4^{3-}) enter the waters mostly due to human economic activity. As a result of anthropogenic contamination phosphorus also gets into the water in the polyphosphate form. However, often more than 90% of the total amount of phosphorus compounds may be organic compounds, or associated with suspended substance.

The major organic phosphorus compounds, found in waters, are nucleic acids, proteins, their degradation products, vitamins, ATP, ADP, carbohydrates, their phosphoric acid esters, phospholipids. The most important inorganic phosphorus compound found in waters (particularly in the sediment phase), is hydroxyapatite, and various phosphorous compounds which have sorbed on particles of clay, carbonate, iron hydroxide. A significant proportion of phosphorus compounds can also be found in the waters in the form of colloidal particles.

Given that phosphorus may be present in waters in a form of several compounds, whose bioavailability is different, it is important to determine not only the total phosphorus content, but also the phosphorus forms.

Phosphorus compounds have a great importance in eutrophication processes of water reservoirs and, if the phosphate content is >0.05 mg/l, with a sufficient quantity of nitrogen compounds, an intensive growth and multiplication of algae and other aquatic plants can begin in the water body under favourable conditions. The phosphate content of the waste water can reach high values, and to get rid of that, special technologies are required. When entering the bodies of water, phosphorus compounds are assimilated in hydrobionts, but, as they decompose, the phosphorus compounds largely accumulate in the sediments. As a result of changes in environmental conditions, the phosphorus accumulated in sediments may be released, creating the so-called internal pollution load.

Silicates are found in natural waters not only in the form of silicic acid anion ($HSiO_3^-$, SiO_3^-), but mostly as polymer compounds and colloids. The most significant source of silicates in waters is the mineral weathering of silicate. Since the silicate weathering intensity is greatly dependent on the ambient temperature, the watercourses of warm climates usually have much higher silicon content than waters in the temperate zone. Silicon is a biogenic element and it is extensively assimilated by aquatic living organisms, mainly diatoms. If the silicon content falls below 0.5 mg/l, many diatom species fail to develop normally, i.e., silicon content in water becomes the limiting element in the development of algae. The silicon content in lakes is typically around 5 to 10 mg/l, the sea and ocean waters contain around 0.5 to 3.0 mg/l, but especially soft waters can have the content of 50 mg/l SiO_3^-. Groundwater silicon content can be as high as 3000 mg/l. Silicon dioxide (silica) solubility increases with rising water temperature and decreasing environmental pH.

Iron can be found in natural waters in more than one form – ionic form (Fe^{2+}, Fe^{3+}), iron hydroxide, oxyhydroxide that both can create water-suspended particles, and may also be sorbed on the solid particle surface in the form of colloidal particles, as well as in the form of humic acid and fulvic acid salts. The fate of iron compounds in the aquatic environment is affected by the oxidation-reduction processes and the presence of oxygen.

Eutrophication is a plant primary production intensification due to rise of nutrient concentration (Table 8.5) in waters.

Table 8.5. Elements required for plant development and their sources in waters

Element	*Source of elements*	*Function*
Macro-elements:		
carbon (CO_2)	atmosphere, living organisms	forms biomass
hydrogen	water	forms biomass
oxygen	water, air	forms biomass
nitrogen	atmosphere, living organisms	protein
phosphorus	mineral weathering, living organisms	DNA, RNA, ATP metabolism
potassium	mineral weathering	protein
sulfur	mineral weathering, sulfates	metabolism
calcium	mineral weathering	metabolism
Microelements:		
B, Cl, Co, Cu, Fe, Mo, Mn, F, V, Zn	Mineral weathering	metabolic functions

«Eutrophic» is a derivative of the Greek origin meaning «well fed.» This name represents the conditions in the water body due to the increase of biogenic elements, when the biological processes are greatly intensified. It is first observed as growth of algae, accumulation of organic matter, and eventually leads to a significant deterioration of water quality.

Generally, the eutrophication is a natural process and it is considered to be one of the basic stages in the development process of water body (Figure 8.7) – from the oligotrophic state, as the life processes develop and biogenic elements are supplied from the catchment area, entering into eutrophic, and finally to become overgrown. At the same time, anthropogenic water pollution can significantly speed up this process and lead to anthropogenic eutrophication. Eutrophic waters are characterized by high biogenic element concentrations in water and sediment (water phosphorus content >20 μg/l), high content of organic substances in the water, high biological productivity of water, muddy water, oxygen deficiency in the demersal zone and typically anoxic environment under the ice in the winter period, the loss of biodiversity while the total mass of living organisms in the waters increase. Oligotrophic waters are clear waters with low organic substance content, low biological productivity, high oxygen content in the water, high biodiversity in the waters, but a low total mass of living organisms.

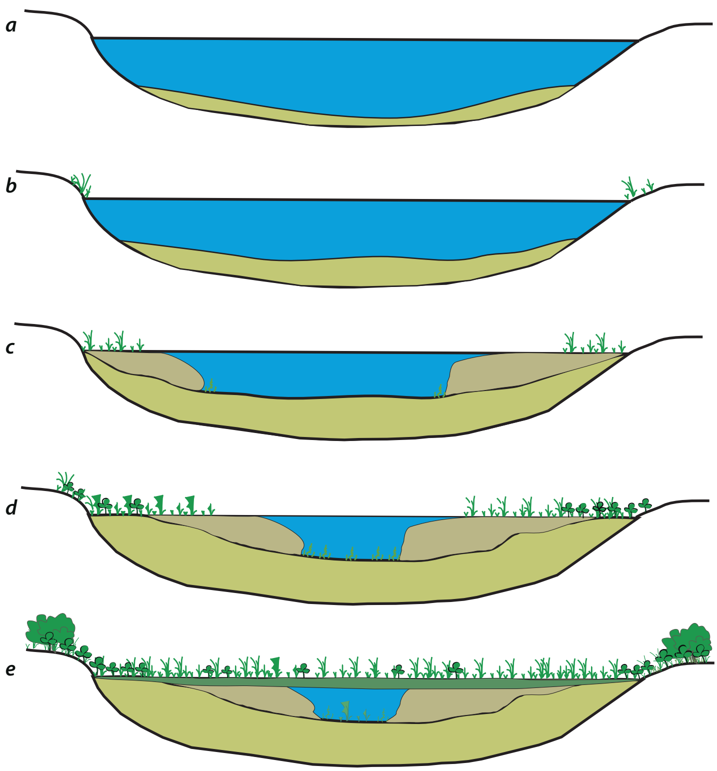


Figure 8.7. The process of lake evolution and overgrowing. ***a*** – oligotrophic waters; ***b*** – the gradual accumulation of organic sediments and biological productivity growth; ***c*** – coastal overgrowth formation and the conversion of water body into eutrophic; ***d*** – most of the water body is overrun by sediments, the foreshore is completely overgrown; ***e*** – lake turns into a swamp.

The process of eutrophication is based on creating optimal conditions for the development of aquatic organisms, which normally requires micro-and macro-elements. If the elements such as carbon, hydrogen, calcium and magnesium are always excessive in natural waters, in reality the development of living organisms is decided by biogenic elements: nitrogen compounds, silicon, but first of all, phosphorus. Consequently, discharge of household sewage and other wastewater, and also entry of surface runoff from agricultural areas in watercourses, start off the eutrophication process. The fact that the eutrophication processes are first of all determined by the presence of phosphorus compounds is proved by the dependence of algae growth on the presence of phosphorus compounds in water. Nitrogen is the limiting element in eutrophication considerably less frequently and it is typical first of all of the marine waters.

The causes of eutrophication are as follows:

1. lake water level decline during excessive lake exploitation;
2. rapid filling of lakes with sludge containing silt from the soil erosion in the catchment area (deforestation, agriculture);
3. direct eutrophication as a result of diffuse or point source nutrient inflow.

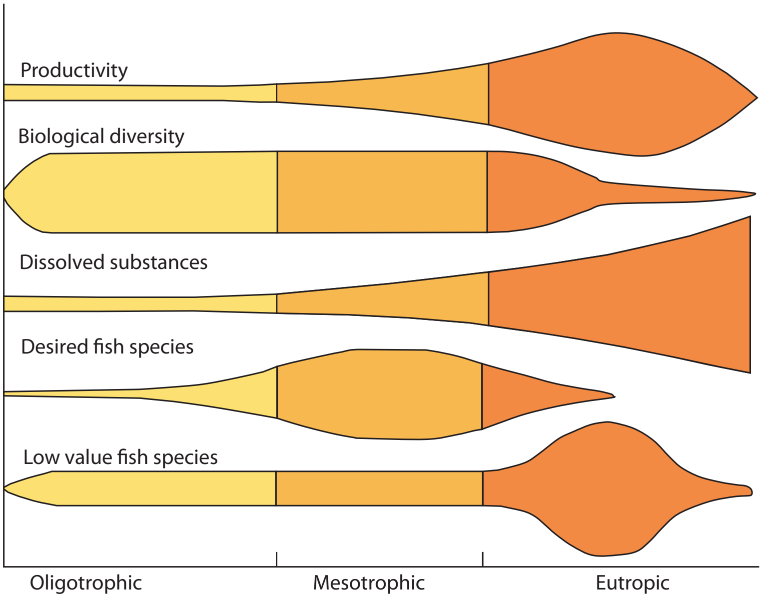


Figure 8.8. Eutrophication effects in the waters

These three main causes lead to the disintegration of the lake ecosystems and the loss of biodiversity in lakes as living environments, as well as the decline of the biodiversity and productivity.

The interrelation of various organism groups or organisms – indicators are used for biological determination of the trophic level in lakes.

Figure 8.9. Eutrophic waters with heavy algal blooms during summer season

To remedy the consequences of eutrophication, different methods are used, but first of all the inflow of biogenic elements must be curbed, i.e., the change of land use as the determinant of eutrophication is necessary. Often the biogenic elements must be removed from the lake ecosystem. Deepening of the lake, sludge removal is one of the effective, albeit extensive and expensive methods, as is the use of biological methods – mowing and removal of vegetation, change of species composition (especially fish) and intensive fishing.

The most significant signs and criteria of eutrophication are as follows:

- increased algae production, often more than 10 times;
- the color spectrum and turbidity of the water intensifies, transparency is reduced to 0.5 m and less, a depth of blue-green algae mass silt and leach reaches more than 2 kg of green mass per cubic meter of water;
- loss of oxygen saturation in the deeper layers, and disappearance of benthic fauna and cold-water spawning fish species;

- deep-water horizons accumulate hydrogen sulfide, carbon dioxide, dissolved iron and / or manganese;
- as a result of algae sedimentation and decomposition, the intensive formation of methane takes place, sediment-bound nitrogen and phosphorus compounds are released in water;
- development of undergrowth and filamentous algae;
- if the water turbidity is increased, the transparency falls below 0.3 m, and rapidly (even within one year) underwater vegetation disappears;
- suffocation of fish under the ice or as a result of intense photosynthesis in summer, which determines the pH increase and promotes intoxication.

The amount of organic material dissolved in waters is characterized by determining the amount of oxygen that is consumed by either chemical oxidation of organic matter (chemical oxygen demand – COD), or as the aquatic living organisms consuming dissolved substances as a result of their life processes (biological oxygen demand – BOD).

The processes in nature, which are characterized by these features, are irreversible.

Water contamination with organic substances always has a very complex character. Organic pollutants are able to actively interact with a variety of naturally-occurring substance groups. Another special feature characteristic of this group of substances is that they are strongly affected (transformed, destroyed) by a variety of living organisms, primarily bacteria, fungi, yeasts.

The complex chemical content of the organic environmental pollutants usually makes it difficult to analyse the waste water containing these substances. Typically, such waste water is analysed by looking at the organic substances at a certain aggregate amount, which is able to consume oxygen, according to COD or BOD values.

On the other hand, the water-dissolved oxygen content might be considered as a different criterion, whose content values show the inflow of biodegradable organic substances into the waters. Figure 8.10. illustrates the general concepts, which characterize the changes in the composition of waters in case of the waste water discharge.

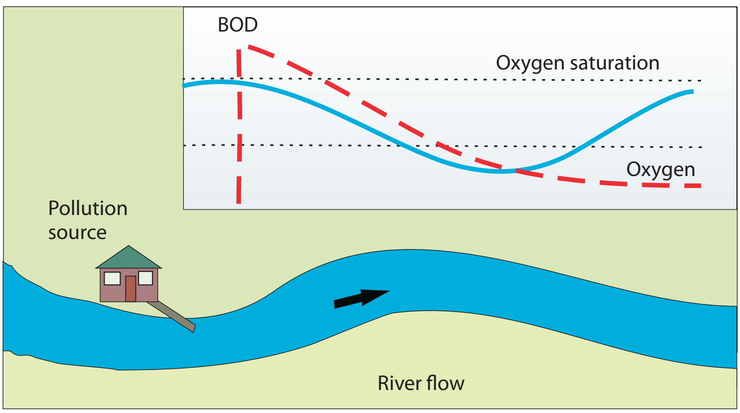


Figure 8.10. Biological oxygen demand and water-dissolved oxygen content changes in the river water, in case of waste water discharge

In case of sewage inlet, the changes in water are characterized by the increasing demand for biological oxygen, decrease of the water-dissolved oxygen content, increase of the nitrogen content (and the nitrogen compounds usually are in the form of ammonium ions). In the event of water pollution with biologically labile substances, typical changes include alteration in water biocenosis (living organism communities) structure, which is primarily related to a drastic drop in biodiversity, and the increase of overall biomass of living organisms.

Only at a certain distance from the point of discharge of pollutants, the water composition is restored to that which is typical to the environment unaffected by anthropogenic action. River pollution with organic substances is caused by industrial facilities on river banks (food and wood processing complexes, paper mills and textile plants) discharging untreated or poorly treated waste water. The specific character of river ecosystem response to this contamination is related to water exchange opportunities provided by the river currents. Depending on the speed of the current and the amount of discharged organic substances, the river ecosystems have certain self-cleaning abilities. The term «self-cleaning» denotes the capacity of microorganisms, plants and other aquatic organisms to break down, consume and mineralize the organic substances injected into the river, including those in their biomass or removing from the ecosystem in the form of minerals and carbon dioxide. The process takes place in several stages, each of which can be assigned to a certain zone downstream of the pollution intake site.

Figure 8.11. Discharge of untreated wastewaters is a common source of river water pollution

Aerobic environment – an environment where the oxygen content is sufficient to sustain the life processes of oxygen-consuming organisms. Anaerobic environment – oxygen-free environment.

Usually there are four distinguishable self-cleaning zones:

1. Degradation zone. In this area of the river water mixes with pollutants. The water becomes cloudy, inadequate for development of water plants and other organisms. However, here species consuming the organic substance particles may reproduce. As the heaviest particles sink to the river bottom, the organic sediment layer is formed.
2. Active decomposition zone. Here the concentration of organic pollutants causes rapid proliferation of water microorganisms, bacteria and fungi, and they commence the biological degradation of organic substances. A vital factor in this process is the oxygen content in the water. All aquatic invertebrates and fish use the oxygen for respiration. However, in the active zone it is also in large quantities consumed by aerobic microorganisms. Therefore the oxygen deficiency is observed here. It is characterized by the biological oxygen demand. While oxygen is still sufficient, the organic substances are degraded by the aerobic microorganisms. As the amount of oxygen decreases, they are replaced by anaerobic microorganisms. In this zone a

large number of microorganisms and a multiplicity of forms can be observed, which depend both on the chemical composition of the waste water and on the quantity of organic particles suspended therein.

3. Regeneration zone. Here from the active disintegration zone the minerals – nitrate ions, phosphate ions and various micro-elements – are borne, which are liberated in the decomposition process of organic substances. Since the active decomposition of organic substances no longer takes place here, the water is slowly recovering the oxygen content, and turbidity decreases. This creates ideal conditions for the development of algae and aquatic plants. As a result, the algae proliferate abundantly here.
4. Purified zone. In this zone the condition of river ecosystem approaches the initial one. Nutrients have been assimilated by aquatic plants. As a result of photosynthesis the oxygen levels in the water have returned to normal. Therefore, the fish and invertebrates characteristic of clean water again appear in the river. However, it should be emphasized that in case of major pollution with organic substances the biological self-cleaning never achieves the original condition of the river ecosystem.

Oil can get into the aquatic environment:
- as a result of various accidents;
- by rainwater runoff leaching from urbanized or industrial areas.

According to the ways of contamination listed above, the water protection measures must be undertaken.

Marine waters can become contaminated:
- as a result of tanker accident;
- with wash and rinse water of tanker ships;
- from oil rigs in the sea.

Figure 8.12. Oil spills from ships is a significant pollution source

Thus, the river self-cleaning process includes logical, sequential changes of many essential indicators. The river self-cleaning process described above is portrayed schematically. In a real situation, its pace is dependent both on the type of waste water and on the velocity of its current.

Pollution of natural waters with oil is particularly dangerous. Like other aquatic environment pollutants, oil is a complex mixture of various substances, which, depending on the oil extraction source, consists of linear hydrocarbons (C_6–C_{25} paraffins), cycloalkanes, aromatic hydrocarbons (mono and polycyclic) and also contains aromatic carboxylic acids, organo-sulfur compounds and other hydrocarbons.

This form of pollution is characterized by leakage of a large mass of oil into the marine waters and contamination of vast territories. Upon entry of oil and its products into the aquatic environment, it quickly spreads along the surface of the water, creating a surface film, for example, 15 tons of mazout leaking for 6-7 days can cover about 20 km^2 of water surface. This condition involves one of the major hazards characteristic to environmental pollution by oil, namely, it disrupts the air exchange between the atmosphere and water, which in turn can lead to fish suffocation and other consequences. Waterfowl landing in the contaminated water, become covered in sticky oil.

Another feature of such a surface film is that many other pollutants are concentrated therein, primarily organochlorine compounds. For example, the pesticide dieldrin concentration factor in such surface film increases up to 10 000 times. In addition, such a surface layer can accumulate heavy metals, particularly mercury compounds.

After entry of oil and its products into the environment, further transformation processes take place. First of all, the volatile oil fractions (benzene, xylene, octane, lower paraffins and cycloparaffins) evaporate.

Further transformations take place through a variety of microorganisms. Since the oil composition is very complex, its biodestruction takes place under the influence of several groups of organisms, each of which has its own specifics. Primary degradation processes result in a new group of compounds, which themselves may not be less toxic than the original oil products, and their further transformations are implemented by different organisms. Of the oil products the first to be degraded are paraffins, and subsequently cycloparaffins. The polyaromatic hydrocarbons are most stable. The total oil oxidation rate depends on the ambient temperature and oxygen content in the water, and this last factor can be used as the indicator of the intensity of contamination destruction processes.

It is estimated that, in order to oxidize 4 liters of crude oil, as much oxygen is consumed, as is contained in 1 500 000 litres of sea water saturated with oxygen. It is contained by a 30 cm thick layer of sea water in the area of 500 m^2. As a result of the degradation process and the mechanical action of waves the homogeneous oil film is gradually being destroyed, initially through formation of the oil droplet emulsion in the water, from which, through evaporation and adhesion, greasy oil clumps are formed, which then are often washed ashore.

Through the natural oil degradation processes the water environment decontamination of the oil pollution is accomplished.

In the past, water pollution with oil was eliminated either by adding a variety of surfactants to the water, which helped to destroy the film on the surface, or carbonized sand, which contributed to the sedimentation of the surface film. However, this approach had a disadvantage – it did not fundamentally eradicate the environmental pollution, but simply transferred it to another location or time postponed?. In addition, the toxic effects of many surfactants were even greater than those of oil products.

Given the urgency of the matter, recently many techniques have been developed to prevent the environment pollution by oil products, among which the preference should be given to the use of selectively operating micro-organisms.

Today, the question arises regarding the contamination of water environment with synthetic detergents.

Synthetic detergents contain a variety of substances that may pollute the aquatic environment:

- bleaches / whitening agents (various oxidizing agents) such as sodium perborate;
- enzymes such as lipase;
- corrosion inhibitors such as sodium silicate;
- fragrances;
- inert substances (fillers) such as sodium sulphate;
- stabilizers, such as magnesium silicate.

However, from an environmental point of view, the most important are two components of synthetic detergents:

1. surfactants;
2. water softeners.

Surfactants are a group of water-soluble organic substances, which concentrate on surfaces and reduce the surface tension of water. The main constituting elements which determine the impact of a substance on the surface tension of the aqueous solution is an asymmetric molecular structure: surfactant molecules consist of two parts – a water-repellent grouping – a hydrophobic part and a – hydrophilic (water attracting) part. In soaps the hydrophobic group has a relatively long linear hydrocarbon residue, and the hydrophilic group is the carboxyl group.

There are the following groups of surface active agents (SAA):

1. Anionactive SAA. The molecules of these surface-active substances are composed of hydrocarbon residue (hydrophobic part) and the sulfato-, sulphonato-, phosphate – or carboxy groups. This is the most important group of surface-active agents, used in manufacturing both liquid and solid detergents. This group of surfactants comprises:
   - soaps, such as sodium stearate $CH_3(CH_2)_{16}COO^-Na^+$;
   - sulphonated aromatic or linear hydrocarbons, for example, $C_{12}H_{25}(C_6H_4)SO_3^-Na^+$, $C_{15}H_{31}SO_3^-Na^+$;
   - higher alcohol sulphates such as sodium dodecyl sulphate, $C_{12}H_{25}OSO_3^-Na^+$;
   - higher alcohol phosphates;

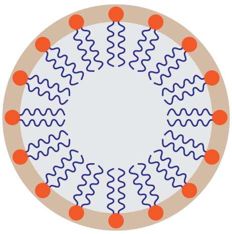


Figure 8.13. Structure of micelle

2. Cationic SAA, whose molecules consist of a hydrophobic hydrocarbon residue and the grouping bearing ammonium ions. The application sphere of this surfactant group is relatively limited, but these substances are used as a disinfectant and antiseptic components in detergents.
3. Non-ionic SAA, in whose molecules hydrophilic residue is made up by ethylene glycol residue. This group of surfactants can be obtained by treating alcohols, fatty acids and phenols with ethylene oxide or ethylene chlorohydrin.

In addition to synthetic surfactants, there are also many natural substances that can be used as detergents, such as casein, saponins, lecithin, lanolin derivatives, and polysaccharides. Surfactants – synthetic detergents – today are considered one of the most important groups of substances whose production is constantly increasing. After the use of these substances, they enter the treatment facilities.

Under the biological treatment conditions, SAA decompose far more slowly than the natural detergents – fatty acids and their salts, and the decomposition process consumes large amounts of oxygen. In addition, the breakdown products invest the water with an unpleasant taste and odour, as well as cause foaming. Of the three types of SAAs the most toxic are the cationic surfactants.

Water softener additives in detergents are needed to reduce the adverse effects of water hardness. These substances bind calcium and magnesium ions in stable complexes. The water softeners used most often are polyphosphates, sodium tripolyphosphate ($Na_3H_2P_3O_{10}$), sodium silicate or organic substances. These substances cause water eutrophication.

The compound which often has a significant impact on water quality is hydrogen sulfide H_2S. Hydrogen sulfide is formed in anaerobic environment, it is easily soluble and one of the few compounds whose amount in water is regulated by the water quality standards. Although hydrogen sulfide is toxic, its presence is felt at significantly lower concentrations than those, which, when reached, begin to cause the toxic effects of hydrogen sulfides.

In general, substances that adversely affect the taste and odour of drinking water are not regulated by any standards. There are several reasons for this. In general, substances which impair taste and smell of water are contained in water in microscopic quantities, and their effect is not toxic.

Water can be contaminated due to the presence of increased amounts of many metals and microelements. Pollutants with a particularly hazardous impact on the aquatic environment are lead, mercury, copper, zinc, cadmium, chromium and nickel. In the last century, when tetraethyllead lead was added as antiknock agent to automotive fuel, 25 000 tons of lead compounds annually entered sea and ocean waters. All heavy metals are highly toxic to aquatic life.

Particularly high toxicity is characteristic of mercury (Hg). The exposure to this pollutant was first noted in 1956, in Minamata Bay, Japan, where more than 100 people died of a massive poisoning and 10 000 more developed serious health disorders. Intoxication was caused by methylmercury contamination of marine products – fish, crabs and shellfish – consumed by coastal fishermen. The pollutant had run into the sea with the sewage of a chemical plant. The mercury salts were used as a catalyst in the production process of acetaldehyde. Due to the accumulation of mercury compounds in the ecological food chain, the content in marine organisms used for human consumption was 500 000 times higher than in the sea water. The mercury poisoning consequences for people who regularly ate seafood included severe central nervous system disorders in the form of a narrowing of the visual field, hearing impairment, speech impairment, loss of reason, unsafe walk and seizures. As the disease causes were not yet cleared, the symptoms were named Minamata *disease*. For many people who had apparently ingested smaller amounts of methylmercury, the symptoms began to appear only after several years, but the children born in the region were observed to have different congenital deformities.

The sources of substances conferring unpleasant taste and odour are different:
1. living organic matter decomposition products;
2. phenols and lignins, which, at water disinfection with chlorine, form chlorophenols with a strong unpleasant smell;
3. algae and bacteria give off many metabolites, whose presence in water may give it the odour of rot, soil, hay, potatoes etc., as well as, for example, a bitter taste.

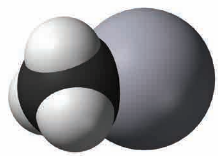


Figure 8.14. Formula of methylmercury

Furthermore, the illness was observed not only in the people, but also in those pets who consume fish – cats. These animals were recorded with behavioral problems – they had lost the aversion to water inherent to cats.

Minamata disease symptoms appeared at a mercury concentration of 10 mg/kg of edible fish. Numerous studies have found that dangerously high contamination with methylmercury has also been registered in other parts of the world, including the northern coast of the Mediterranean Sea, NE Atlantic and the Baltic Sea. Entry of mercury compounds in the Baltic Sea mainly takes place with river water (8-44 t/year) and precipitation (4-29 t/year) they reach the sea in significantly smaller amounts by the waste water of the cities and factories located on the coast. Marine organisms accumulate methylmercury. The biggest concentrations of mercury are found at the highest stages of marine ecological food chain – the bodies of seals, and the concentration increases significantly with age.

The human health hazard lies in the increased consumption of the marine animal products containing growing quantities of mercury. The organisms of the predatory fish living and feeding in the Baltic Sea coastal area contain methylmercury concentrations exceeding 0.5 mg/kg. In the Mediterranean Sea high mercury content was found in swordfish. Frequent intake of mercury-contaminated fish may cause health disorders. Particularly sensitive to contamination are the human foetus and growing child's body.

One of the indicators that can be used to characterize the received doses of mercury in the body at different periods of human life is the content of this metal in hair. Studies in Japan have shown that the mercury concentration in the hair of the people who regularly, for several days a week had consumed seafood products, exceeded that of the people in the control group 5 to 10 times. However, in accordance with scientific findings, also the people of the studied control group, although to a much lesser extent, were exposed to mercury pollution, which was contained in the consumed agricultural production. Mercury compounds enter the agricultural products as a result of applying mercury-containing grain fungicide treatment substances. The chemical composition analysis of hair carried out on the citizens of European countries, showed that the mercury concentration there was similar to that found in the control group of Japan. It indicates that in this region there is also a heightened background of mercury pollution. Data from these studies at the end of 1960s prompted a number of European governments to adopt more stringent regulatory measures for mercury compound use in industry and agriculture.

Ecologically no less dangerous are the cadmium compounds. Cadmium is one of the most mobile and biochemically active heavy metals. It accumulates in the kidney cortex, causing hemorrhages. When ingested, cadmium binds itself to proteins and accumulates in the kidneys and liver. In the Baltic Sea cadmium, similar to mercury, is brought mainly by river water and atmospheric precipitation. The concentrations of this metal in fish here range from 2 to 200 μg/kg, and in molluscs – 1300 to 10 800 μg/kg of the body weight. Cadmium, like many other polluting elements, tends to accumulate in the ecological food chain. Threat to human health is posed by increased accumulation of cadmium in those links of food chain – marine organisms widely used in food. One of these fish species is herring, in whose body an increase in cadmium content has recently been observed.

Figure 8.15. Lead historically has been widely used as a source of pipes for water supply thus affecting drinking water pollution level with lead

One of the heavy metals of greatest ecological importance and toxic to living organisms is lead. In the last century large quantities of lead came into the sea and ocean ecosystem with industrial effluents and emissions of tetraethyllead used in road transport. Due to stricter environmental legislation, waste water treatment technology improvements and the introduction of unleaded automotive fuel, since 1980s the lead concentrations in the have been decreasing, as shown by the analysis of fish and molluscs.

Biological pollution of waters is caused by inflow of untreated municipal or industrial wastewater from industrial plants and residential areas. Biological pollution consists of pathogens – viruses, bacteria and microscopic fungi, as well as a variety of organic substances subject to fermentation processes. Biological pollution also manifests itself as the appearance of species not characteristic of specific water bodies – the so-called invasive species. Pathogenic microorganisms cause public health and hygiene problems in bathing places. This contamination is evaluated according to the presence of intestinal bacillus *Escherichia coli* in the water sample. In itself, this bacillus is harmless to humans, they live as symbionts in the human intestinal tract and as a result of their life processes produce physiologically important substances, including vitamin B12. However, the presence of *Escherichia coli* serves as a faecal contamination indicator, but this contamination may conceal a number of pathogenic microorganisms, incl. infectious hepatitis, cholera, typhoid and dysentery agents, as well as staphylococci, streptococci, and pathogenic fungi. Humans become infested with these microorganisms while swimming in biologically contaminated water, so the most popular swimming sites on sea coast, including seaside, in summer season are regularly monitored regarding biological contamination and, if *Escherichia coli* in water sample exceeds a certain level, vacationers are warned not to go swimming.

Water contamination with pathogenic microorganisms also makes the produce of mollusc farms – oysters and other edible

Sources of water pollution in Uzbekistan are:
- contamination as a result of agricultural activity;
- contamination as a result of industrial activity;
- contamination with household and municipal waste in urban and rural regions.

molluscs – dangerous for consumers, as it is shown that many species of molluscs in their bodies accumulate significant amounts of pathogenic viruses. It is believed that in a number of cases contaminated edible molluscs have caused localized epidemics of infectious hepatitis.

Of the industrial companies, the largest biological contamination in seas and oceans is created by insufficiently treated waste water from paper mills, sugar mills, meat processing and other food production companies, containing large amounts of organic substances subject to fermentation processes. In these processes, large amounts of oxygen are consumed, water turbidity increases, and it has a very negative overall impact on aquatic organisms.

At major rivers water mass contamination is increasing downstream. Estuarines of Syr Darya and Amu Darya are characterized by increased index of water contamination over last years, however, river pollution during last years, is decreasing.

Exceeding the permitted usage of agrochemicals results in a high level of contamination of agricultural land and water resources. Industrial production is contaminating water with mainly heavy metals, phenolics and petroleum products. Industrial, household and municipal, manifold and drainage waters, discharged in rivers, contain many pollutants, concentration of which in average is 2-10 times greater than permissible concentrations for household and drinking needs, and also fishery needs. The volumes of contaminated waters of household discharged into rivers have been decreasing over the last years. However, the degree of purification is not sufficiently high. Low effectiveness of water treatment facilities (50-70% from set capacities) is a reason for high concentration of pollutants, discharged in surface waters and drops in the area. After purification waste waters have elevated concentrations of ammonia ions and nitrites. A particularly difficult situation is observed in regions with a deficit of water resources (Karakalpakstan, Khorezm, Buchara) and in regions with a high concentration of industrial output (Tashkent, Fergan, Samarkand, Navoji industrial districts). Approximately 1-5% of the water used in industry is discharged without purification. Most rivers of the region in their lower and middle streams have an increased water mineralization: from 1-1.5 g/l – in the middle stream, up to 2 g/l and more in lower stream. In the lower reaches of river Amu Darya an excess in mineralization and water hardness, also in sulfates, chlorides, phenolics and silica is permanently recorded. Water contamination with mercury and fluoride is approaching limit values.

The main water arteries of the Uzbekistan became almost unfit for the drinking water supply due to absence of systematic fresh water releases and discharges of waste water in river from irrigated soils with excessive mineralization, polluted with pesticides and mineral fertilizers. The provision of the population with fresh drinking water is particularly important. Consequently, in Karakalpakstan fresh water supply is, on the average, 61.5%, while in Berunijskij region – 36.3%, in Shumanijskij – 32.5%, in Amudarjinskij – 28.7%. In total, more than a third of population of the country is consuming an insufficient amount of fresh water according to the state standard.

Bibliography

Freeze R. A., Cherry J. A. (1979) Groundwater. New Jersey: Prentice-Hall Inc.

Kļaviņš M., Rodinovs V., Kokorīte I. (2002) Chemistry of surface waters of Latvia. Rīga: LU.

Kļaviņš M., Cimdiņš P. (2004) Ūdeņu kvalitāte un tās aizsardzība. Rīga: LU Akadēmiskais apgāds.

Manahan S. E. (1999) Fundamentals of environmental chemistry. Boca Raton: Lewis Publ.

Praktiskās hidrobioloģijas rokasgrāmata (1995) Rīga : Vide.

Švarcbahs J., Sudārs R., Jansons V., Kļaviņš U., Dreimanis Ē., Bušmanis P. (2001) Ekoloģija un Dabas aizsardzība. Jelgava: LLU.

Water use and management (2000) (Ed. L. C. Lundin) Uppsala: The Baltic University.

Национальный доклад о состоянии окружающей среды и использовании природных ресурсов в Республике Узбекистан (1988-2007). Госкомприроды. Ташкент, 2008. – 298 с. Accessible: *www.econews.uz*.

Окружающая среда и безопасность в бассейне Амударьи. ЮНЕП, ПРООН, ЕЭК ООН, ОБСЕ, РЭЦ, НАТО. 2011. – 11 с. Accessible: *www.unep.org*.

Вода жизненно важный ресурс для будущего Узбекистана. Ташкент, ПРООН. 2007. – 128 с. Accessible: *www.undp.uz*.

Большое Аральское море в начале XXI века. Москва: Наука 2012. – 229 с.

Экологический обзор Узбекистана, основанный на индикаторах. ПРООН, Госкомприроды РУз. Ташкент 2008. – 88 с.

Central Asia Atlas of natural resources. ADB. 2009. – 173 с.

Programme World heritage. Accessible: *www.iucn.org/*.

World Water Council. Accessible: *www.worldwatercouncil.org*.

Water Pollution Guide. Accessible: *www.water-pollution.org.uk/*.

Clean Water Act. Accessible: *www.epa.gov/*.

Water Pollution and Environment. Accessible: *www.webdirectory.com/Pollution/Water_Pollution/*.

From the glaciers to Aral Sea. Water Unites. Accessible: *www.waterunites-ca.org/book.html*.

9. POLLUTION OF SOIL

Pollutants quite often penetrate soil, affecting the organisms that live there. However, the effect of the presence of pollutants in soil or the lithosphere on both terrestrial animals and ecosystems is much more considerable as these substances accumulate in food chains. The main specific feature of the pollution of the lithosphere and soil is its rather limited dispersal from the sources, determined by the properties of materials that compose the soil and lithospheric rocks. At the same time, the mobile component of the soil environment – water, or, more exactly, the underground water – can disperse the pollutants quite quickly. Thus, the soil and lithosphere environmental pollution concentrates at its outlets yet can quickly dissipate, and it intensively interacts with the soil-forming rocks. Another significant specific feature of the soil environment is that the degradation processes of pollutants there take place relatively slowly because the availability of nutrients, water and oxygen indispensable to the life of micro-organisms is often quite limited. The soil environment and the lithosphere can be contaminated by substances that have entered them directly or through atmospheric precipitation or water. Sulphur and nitrogen oxides, entering soil with atmospheric precipitation, can substantially change its composition and affect even groundwaters.

Figure 9.1. Cotton field in Uzbekistan

Waste dumping is a significant source of soil degradation, and it may cause soil contamination not only locally but also on a regional scale, and even in deep groundwater. Underground disposal of pollutants – for example, pumping them more than one kilometre deep into the ground – may delimit their immediate action; however, the consequences may come about in the more distant future.

Virtually all groups of major pollutants – including organic compounds (volatile organic and halogenated organic compounds, oil products, easily degradable organic substances) and inorganic compounds (radioactive elements, heavy metals, toxic trace elements) – cause the soil and lithosphere contamination.

After the nuclear reactor accident, the fallout of radioactive isotopes (as seen in the ^{137}Cs example) occurred for the most part in the region of the accident site, whereas a significant part of radioactive elements was carried away with air masses and reached even the Scandinavian countries.

The soil contamination caused by human activity can be not only local; it may also affect vast territories – as it happened, for example, as a consequence of the Chernobyl nuclear disaster (Figure 9.2), and the radioactive contamination also gradually permeates the groundwaters.

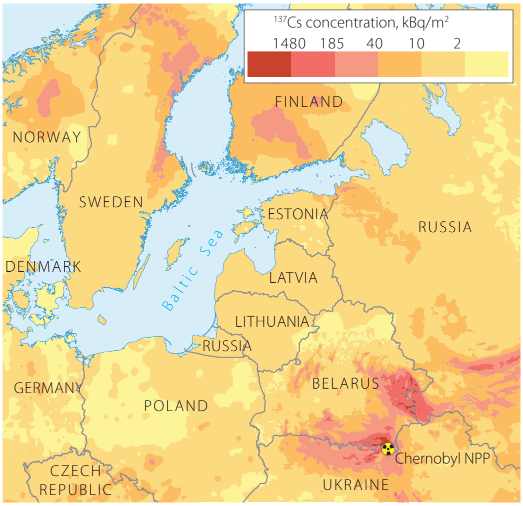


Figure 9.2. Soil contamination in central and northern Europe after the Chernobyl nuclear disaster

Soil environment and the lithosphere can be contaminated by the substances which have gained access thereto directly as well as the substances arriving with atmospheric precipitation or waters. Sulfur and nitrogen oxides, brought by precipitation into the soil are able to change its composition significantly and even to affect groundwater.

A significant source of soil and lithosphere pollution is the dumping of waste, which may lead to localized, but in the event of pollution dispersion, also regional soil or even quite deep groundwater pollution. Deposition of pollutants underground, such as pumping them more than a kilometre in depth may limit the immediate effect of pollutants, but the consequences of such action may become manifest in the future.

Significant soil contamination can occur as a result of agricultural activities, especially due to the use of incorrect methods. Agricultural activities may lead to contamination of the soil with biogenic elements, residue of crop protection products. This type of exposure can completely destroy soil fauna.

It is believed that the soils can have quite a significant impact on human health. Soil composition may affect the plant composition growing in it, and therefore the human food composition. The soil content affects the amounts of microelements consumed by humans with food. The example of such microelements is selenium, whose deficit or overly high amounts in human nutrition can cause specific diseases. Similarly, fluorine, arsenic and boron content in the soil can have a significant impact on the health of animals and humans living in the respective region. There is evidence that the prevalence of gastric cancer in certain cases is linked to the characteristics of soil composition.

The pollution of the very outer layer of Earth's crust is mainly due to mining activities as a result of which man removes chemical elements from the interiar of the Earth in the form of minerals, and in the course of recycling, incineration or other processes in the form of pollution returns them into the Earth's crust. As a result, soil, ground, groundwater properties and chemical composition change, which in turn affects the processes in the biosphere, the quality of drinking water and food.

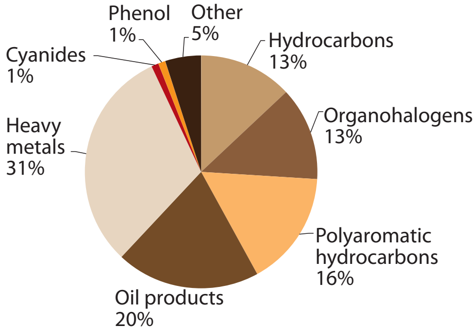


Figure 9.3. The most important groups of substances, which are characteristic of pollution of urban and industrially used soils in EU countries

The second most important cause of pollution is the substances synthesized by humans themselves (such as pesticides) that do not occur as a result of natural processes under natural conditions. In most cases they cause much larger problems to human living

Sources of pollution, depending on the pollutant dispersion, are divided into two types:

- point source or concentrated pollution;
- diffuse or dissipated pollution.

environment and nature as a whole than the chemical elements or their compounds existing within the Earth's crust under natural conditions. Most of the pollution that enters into the deeper layers first of all enter the soil and affect soil processes and fertility.

Point source pollution is created, for example, by oil and petroleum product leakage from pipelines, landfills, vehicle wash and fuelling stations, and other sources. The main sources of diffuse pollution are agricultural activities such as treatment of grain with pesticides, as well as dissemination of various chemicals with precipitation. Much of the contamination from point source and diffuse pollution enter into the ground water, which can affect the quality of drinking water.

The soil is considered to be the central node in terrestrial ecosystems, because the whole ecosystem substance circulation and energy flow runs through it. At the same time, the soil is also an ecosystem component, which accumulates the environmental pollution created as a result of human activities. Next, depending on the circumstances, this pollution can reach groundwater, and be discharged into rivers and lakes with surface runoff, or remain in the soil indefinitely, affecting terrestrial plants and animals.

The main sources of soil pollution today are agriculture, industry and transport. In agriculture, soil contamination results from fertilizer application in fields – the use of both organic and mineral fertilizers, pesticide use to fight the weeds and pests of agricultural crops.

Industrial plants can contaminate the soil with solid production waste material, as well as with atmospheric emissions – gaseous substances and dust, which can be transported for long distances with the air masses and deposited in the soil or leach into the soil with precipitation water. Unlike factory pollution, which is of a point source type, vehicles – cars, aircrafts, trains – create gas and dust pollution, which is diffuse, it spreads in all directions from the motorways, thus contaminating wide areas and also the places where there are no industrial enterprises. A particular type of soil contamination is the radioactive contamination, which has its origins in the nuclear tests or nuclear power plant accidents.

9.1. Contamination of soil with organic substances

The importance of the Earth's upper crust contamination by oil products must be particularly emphasized. Soil, ground and groundwater are contaminated with oil and petroleum products due to misuse of technology or accidents in oil extraction, processing, transportation and storage facilities. The most typical sources of pollution are oil mining and processing, oil and petroleum product pipelines, oil transport, railway territories and locomotive depot areas, fuel stations, motor transport depots, fuel storage areas and abandoned military sites.

The soil may contain oil and oil products in the following phases:
1. in gaseous phase among the soil mineral particles;
2. as a nonaqueous liquid phase in the soil;
3. as a solution in the soil water and groundwater;
4. adsorbed on soil particle surfaces;

In cases of oil and petroleum product spillage, when they enter the soil, they become subject to a wide variety of transformation processes. First, there are chemical processes: oxidation, reduction, hydrolysis, photolysis and hydration processes. Secondly, physical and mechanical processes: evaporation, sorption, dissolution, viscosity and density change. Thirdly, biological processes: biodegradation, biotransformation, bioaccumulation and toxicity changes. First of all the volatile oil fractions (benzene, xylene, octane, lower paraffins and cycloparaffins) evaporate. Migration of oil products is directly dependent on their solubility in water. The best solubility in water is typical of aromatic hydrocarbons. 70-90% of the total weight of the aromatic hydrocarbons pass into an aqueous solution, regardless of the fuel type. Heavy oil product residues due to their physicochemical properties are almost insoluble in water and therefore move very little. Migration of oil products in soil is affected by the soil and its composition. Sorption characteristics of the soil and the ground below it are determined by the mineral properties, their structure and amount. Sorption consists of adsorption and ion exchange.

Physical adsorption (sorption without the chemical interaction of substance to be sorbed and the sorbent) should be distinguished from chemical adsorption – chemisorption (the substance to be sorbed and the sorbent interact chemically).

The highest sorption capacity is characteristic of clay and the organic substances present in soil. The organic substances and clay particles absorb the components of petroleum products very well. The clay layer may form a geochemical barrier, and as a result the pollution flow movement is impeded or stopped completely. In turn, the sand in the ground with good aeration properties and due to good filtration properties of sediment creates prerequisites that any contamination on the surface of the Earth causes corresponding groundwater pollution. In cases of gasoline leak into sand soil, the petroleum product can reach the depth of more than 5 m within a few hours' time or overnight.

When oil products access groundwater, due to their physical characteristics and the fact that their density is lower than the density of water, they accumulate in the upper layer of the ground water (on the surface of the water-bearing layer), and in many cases a loose (floating) oil layer is formed here.

Natural environment has a selfpurification ability. Selfpurification of soil and groundwater comprises the entire set of processes directed toward restoration of the soil, ground and groundwater to the original composition and properties. In the soil oxidation, biological processes are of greater importance. In the absence of oxygen, oil product degradation slows down. The degradation rate of oil products is influenced by the presence of nutrients (nitrogen, phosphorus and potassium compounds). These substances contribute to the biochemical degradation of oil products. Biodegradation is important for soil and ground selfpurification. In nature, there are many microorganisms that use oil products as nutrients.

Pesticides (from Latin *pestis* – disease and -*cide* – to kill) are chemical compounds that produce toxic effects on certain groups of living organisms, from bacteria, mould fungi to plants and warm-blooded animals.

Soil microorganisms (bacteria and soil fungi) convert compounds harmful to nature and humans into less toxic compounds. The intensity of oil biodegradation process is determined by pollution, the environment and the characteristics and properties of the microorganisms therein. In the biodegradation processes the oil products serve as an energy source for microorganism activity. Microorganisms metabolize the pollution for the maintenance of their life processes and reproduction. The end product of microbiological biodegradation is carbon dioxide, water and biomass. Generally, the natural biodegradation process occurs more efficiently in fertile soils with sufficient quantities of nitrogen and phosphorus. Biodegradation of petroleum products in oxidative conditions decreases in the following direction: normal alkanes → iso-alkanes → aromatic compounds → cyclic alkanes → high molecular weight cyclic compounds, asphaltenes, resins.

The most important groups of pesticides are:

1. insecticides – to exterminate insects;
2. herbicides – weed control;
3. fungicides – control of fungi;
4. zoocides – destruction of vertebrates;
5. repellents – to repel harmful insects;
6. attractants – to attract pests;
7. defoliants – designed to promote fall of leaves;
8. desiccants – dry the leaves, causes the seeds to mature

Environmental quality can be significantly affected by the substances used in agriculture – pesticides.

Currently there are about 30 000 known kinds of pesticides, which are divided into categories based on their application requirement.

Pesticides are classified according to their chemical composition and mode of action. Their main groups are organochlorine compounds (DDT, heptachlor, aldrin, dieldrin, etc.), organophosphorus compounds and pesticides, based on carbamates and chlorophenol acid. The most widely known representative of organochlorine pesticides is DDT. The largest quantities of pesticides are used to raise buckwheat and various oil plants. In some cases, the amount of use pesticides reaches 5000 g per hectare.

As a result of using large quantities of pesticides, they are accumulating in the soil and can affect the quality of agricultural products and human health. Pesticide distribution and accumulation in soils is dependent on their stability, which in turn is influenced by their chemical structure, physical and chemical properties, and biological stability. Pesticide sorption and migration in the soil is also significantly affected by the soil characteristics, weather conditions, including the amount of precipitation. As a consequence of adsorption processes (resulting from physical, chemical and ion exchange), pesticides accumulate in the surface layer of soil to a depth of 20 cm. The possible contamination of underground waters

Figure 9.4. DDT. Formula of 1,1,1-trichloro-2,2-bis(4-chlorophenyl) ethane (DDT)

by pesticides is determined by their extensive use in agriculture. One of the main factors contributing to the migration of pesticides in groundwaters is their solubility. If organochlorine pesticide solubility is some milligrams per liter, other pesticides may have a solubility of 100-1000 mg/l. Over the course of time, as pesticides leak into groundwater, they can be washed into the underground waters – the source of drinking water.

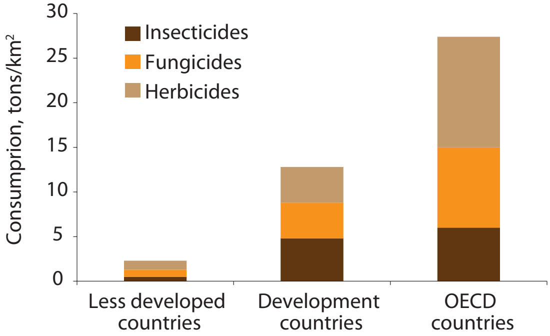


Figure 9.5. Pesticide amounts in the countries with different development paths

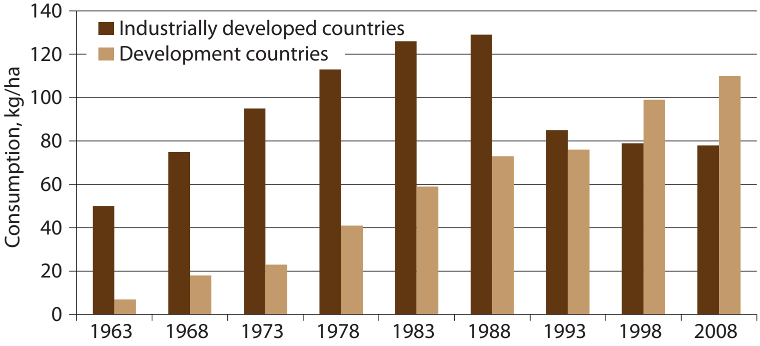


Figure 9.6. Pesticides used in the countries with different development paths

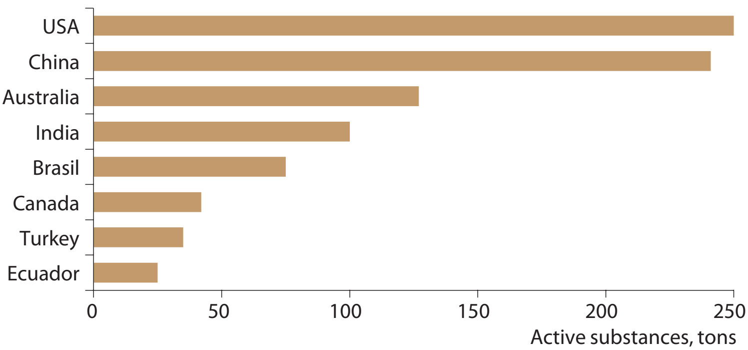


Figure 9.7. Amounts of pesticide use in different countries of the world

The negative effects of pesticide use on the soil ecosystems are related to the fact that these chemicals have an impact not only on pests, for whose destruction they are intended, but also on other components of the ecosystem. Moreover, many of the pesticides prove to be substances or a great chemical persistence and may accumulate in the ecological food chain: soil – plants – herbivores – carnivores. Pesticides do not remain on the field, where they have been sprayed. Air currents and winds easily pick up the volatile substances and carry them into the upper layers of atmosphere and distribute them all over the planet's surface. Thus, they end up in the places that are far away from intensive farming areas – ocean islands and the Arctic. The ability to accumulate in the ecological food chain makes the pesticides released into the environment potentially dangerous it even in very small quantities. Due to the characterstics described above, the pesticides account for the world's most serious environmental problems.

The impact of pesticides can be acute and chronic. In case of an acute impact, as a result of the pesticide exposure the extinction of the entire species or part of it when in contact with the toxic substance can be observed. In Europe, the intensive herbicide use in grain fields to combat weeds resulted in disappearence of flowering plants such as cornflower, corn cockle, the forking larkspur, field poppies and other – the species so characteristic of corn fields in the past have almost completely vanished in very large areas. Severe ecological consequences were brought by herbicides in the middle of the last century, during the Vietnam War. U.S. soldiers sprayed the herbicides from airplanes to achieve jungle defoliation – tree and shrub foliage thinning. For this purpose 2,4,5-T (2,4,5-trichlorophenylacetate) and 2,4-D (dichlorophenyl acetate) were used. These substances in high concentrations impact the cell layer at the leaf petiole base, and as a result the leaf is detached from the branch. Most commonly, after exposure to the herbicide the tree is able to renew its foliage. However, a particular sensitivity to these herbicides was manifested by mangrove woods growing in Vietnam's low, swampy areas, and in these woods the prevalence of dominant shrub species declined catastrophically.

It is important to note that in the course of 2,4,5-T production 2,3,6,7-tetrachlorodibenzodioxine is created, which is generally contained by the herbicide in the form of admixture. Even in tiny concentrations dioxins cause teratogenic effects in animals and humans – severe congenital malformations, and resulted in dramatic effects for many years after the Vietnam War. During 50s of the last century in the south-eastern states of the United States the combat was carried out to destroy the introduced red ants. In the course of three years, from aircrafts, 110 000 km^2 were covered with granular heptachlor and dieldrin, in total spraying 1 km^2 with 1.4 to 2.5 kg of insecticides. As a result, many passerine birds, skylarks and starlings as well as reptiles were killed; the number of insects living in the soil decreased by 40%, but the ants was not completely destroyed.

Chronic exposure may result in disturbed reproductive capacity of the organisms, the birth rates are reduced, or mortality increases. If the individuals of a population become infertile, or unable to perform reproductive functions normally, the population is at a risk of extinction. Such chronic exposure usually becomes manifest, as different species of organisms accumulate pesticides in the ecological food chain. It turns out that plants can absorb small amounts of pesticides from the soil through the roots. Several studies have shown that further concentration of insecticides in the ecological food chain is largely dependent on the type of feeding characteristic to species. A lower insecticide concentration was found in the organisms of herbivorous birds, the concentration in omnivorous species is higher, but the greatest concentration is observed in the organisms of the birds of prey.

One of the sources causing bird poisoning and death is the mercury-containing fungicides and grain mordants. These are used as pre-sowing treatment of seed to protect the seed from pests and the effects of microscopic fungi. Swedish researchers in 1960 concluded that a decline in bird populations in the region is due to their chronic poisoning with fungicides. Mercury content in liver and kidneys of dead pigeons reached 8-45 mg/kg, in those of certain passerine grain-eating birds – 11-136 mg/kg, and in those of gallinaceous birds – 28-150 mg/kg. Through the ecological food chain the mercury entered birds of prey, in whose bodies it reached an average concentration of 100 mg/kg.

The extensive use of DDT in agriculture is the main cause of the decline in populations of birds of prey in many regions of the world. Chronic poisoning with this pesticide its chemical transformation product DDE causes physiological changes in the bodies of birds, as a result the females become sterile, the start of the oviposition period is delayed, the number of laid eggs is reduced. In addition, the decrease in eggshell strength is observed and, consequently, there is an increase in destruction of juvenile birds already in embryonic stage.

Population of a species may also suffer even if the pesticide does not affect it directly, i.e., as a result of indirect exposure to the toxicants. It is possible in cases where the particular species is trophically related to a species sensitive to the toxic effects. Decline or disappearance of food resources may prove to be critical for a given species. For example, the disappearance of field poppies in large territories of Europe caused population decline of a number of insect species, which were feeding on this plant. After the use of herbicides the vegetation does not develop after harvest on the fields. This reduces the food base and hiding places for a number of animal species, such as grey partridges. Using the insecticide sevin to combat locusts in South Europe, it was found that the pesticide treated areas had 86% reduction in the number of birds. Given that birds were not hurt by sevin as a chemical, the only explanation was the extinction of food resources – insects.

The species which are tolerant to pesticide exposure can reproduce even if as a result of pesticide exposure their competitors or natural predators are killed. Very often it has been observed that, as a result of pesticide use along with the targets – harmful organisms – their natural enemies are also destroyed. Often this is the reason for a new, even greater multiplication wave of the parasites after the effect of pesticide has already expired. It has been proved that in case of pesticide use the worst affected are the populations of the pests' natural enemies. They can even be completely destroyed locally. A similar situation was found regarding the cotton pest management in the United States and South America. Systematic use of pesticides totally destroyed the natural enemies of pests. As a result, the pesticide dose and frequency of treatment had to be constantly increased until a vicious circle was formed: the pest population growth required to increase the treatment with pesticides, but each new treatment led to new multiplying of parasites.

Over the last 10-15 years volume of pesticides and mineral fertilizers usage in Uzbekistan reduced 3-4 folds. Despite the significant cut down in consumption of chemical compounds in agriculture, the problem of soil contamination with residual amount of toxic substances is not losing the actuality. Over the period since year 1990 to 2006 a tendency of decrease of average level of irrigated soil contamination with residual DDT in Uzbekistan has been observed and the number of cases of exceedances in permissible limits in samples collected decreased from 39.2% to 21.1%. Increased level of soil contamination with residual DDT still persists in Andikansk and Fergansk regions and is 2.4-6.1 of limit values.

9.2. Contamination of soils with inorganic substances

When growing a variety of agricultural crops and harvesting the yield, the main plant nutrients – nitrogen, phosphorus, potassium, and microelements such as magnesium, iron, boron, etc., which plants require in lesser quantities, are removed from the field. If the content of these elements in the soil is not compensated, the soil degrades and becomes unsuitable for crop production. Therefore, to maintain soil fertility and increase crop yields, natural and artificial fertilizers in agriculture are extensively used.

Under intensive farming conditions mineral fertilizers (superphosphate, potassium chloride, ammonium nitrate and others) are widely applied, and the goal is to provide the necessary balanced nutrient quantities for the agricultural crops. Due to economical reasons, these fertilizers are usually as raw products, therefore with each dose of fertilizer the soil could be polluted with certain quantities of toxic metals and their compounds. For example, superphosphate contains metals such as arsenic, cadmium, chromium, lead, vanadium, cobalt and others. These elements, along with pesticide residues, accumulate in the soil over a long period of time and contaminate it.

Soil pollution also consists of excessive mineral and organic nitrogen and phosphorus amounts. Some of them are leached from the soil into groundwater, wells and watercourses. However, agricultural crops also are subject to the increased intake of nitrates, for example, spinach, in which their quantity, depending on the availability of nitrogen compounds in the soil, may vary between 1.4 to 3.5 g/kg. Increased phosphorus and nitrogen discharge into rivers and lakes causes eutrophication. Furthermore, high concentrations of nitrates in drinking water and consumable plants can cause disease in humans. During industrial processing, including conservation and preservation, as well as consuming nitrate-rich vegetable products into the human intestinal tract, nitrate ions NO_3^- turn into nitrite ions NO_2^-. In the human body they interact with the haemoglobin in red blood cells – erythrocytes, which ensure the oxygen transfer in the organism. As a result, methaemoglobin is formed, which is incapable to bind oxygen and causes serious illness – methemoglobinemia, a disorder resulting in the oxygen starvation in the tissues of the body, despite the fact that breathing is normal. In addition, it has been established that nitrates in human intestinal tract can also turn into nitrosamines, which are considered carcinogenic compounds.

A number of heavy metals that accumulate in the soil as a result of fertilizer over-use are in the form of insoluble compounds, which at the given conditions can not be consumed by plants and microorganisms and, therefore, they are not biologically dangerous. Such a set of sedentary chemical elements are chemical «time bombs». Due to some changes in the external conditions (such as human economic activities or climate change, increased soil acidity) these compounds change into a soluble form and may pass into ecological food chains with all the ensuing dangerous consequences.

It is to be recognized that one of the major factors of soil fertility are organic fertilizers, whose misuse can locally cause high levels of nitrogen pollution. This situation has been observed in many European countries, including the Netherlands, Denmark and Germany.

A very serious environmental problem today is the use of sewage sludge as field fertilizer. Wastewater treatment plants in the world every year accumulate thousands of tons of sludge, which form huge piles at the treatment plants. Since sewage sludge is rich in phosphorus and other plant nutrients, it was recommended to address the sludge problem by using it as a fertilizer for growing agricultural crops. However, the chemical analysis of sludge shows that it also contains a lot of harmful chemicals – organic compounds and heavy metals, which enter the sludge during the factory and urban waste water treatment process. Thus, the harmful substances which a man has tried to get rid of in wastewater treatment process, and which are concentrated in one place, are dispersed again over a wide area and injected into the soil from where they can be ingested by plants or leach into groundwater. Many researchers have warned against the dangers of such practice to environment.

Industrial pollution is caused by a variety of manufacturing processes associated with processing of substances and materials, power generation and fuel use in manufacturing processes. The most important is the industrial pollution, which is ejected into the atmosphere from the factory chimneys. It consists of gases, aerosols and dust particles, which in the air masses are carried over long distances, during the precipitation formation processes dissolve within the water droplets in the atmosphere and eventually settle or fall on vegetation or soil. The chemical composition of industrial pollution is largely dependent on the substances used in the production and technological processes. It is as diverse as the industrial production, therefore in each particular case the industrial pollution interaction with the environment is specific.

Of all the industrial enterprise types, the most important in the context of environmental pollution are considered:

- chemical complexes;
- smelting companies;
- mining companies;
- building complexes;
- heat-electric generating plants.

A very topical problem in the 20^{th} century was sulfur-containing industrial emission impact. Most industrial plants and heat-electric generating plants used the coal as fuel, but in its combustion process great quantities of sulfur dioxide SO_2 are released. This gas dissolves in precipitation water to form acid rain, therefore much attention was paid to research the ecological effects of soil acidification. It has been found that the acid rain most of all affects plants and soil microorganisms.

Since the the end of 1980s the production technology improvement, introduction of filter systems and replacement of coal as a primary fuel with natural gas, sulfur-containing emissions are reduced considerably. However, environmental problems caused by acid rain have not become less acute, because due to the rise in car ownership and, consequently, the amount of car exhaust, nitrogen oxide emissions in the world have increased significantly, which, dissolving in atmospheric precipitation water enter the soil in the form of ammonium NH_4^+ and nitrate ions NO_3^-.

Near the mines and smelting plants the soils are profusely contaminated with heavy metals. Under severe pollution conditions over a wide area around the metal smelting plants the so-called industrial deserts develop, where almost no vegetation or animals are found. An example of such a desert is the surroundings of the non-ferrous metal production complex «Severonikel» built in the North of Russia. Forest soil pollution with heavy metals has a negative impact on soil microorganisms and fauna.

Heavy metals enter the lithosphere and mainly its upper layer – the soil – as a result of:

- industrial activities;
- agricultural activity, during fertilization and liming of the soil or irrigating territories;
- waste storage (household and industrial);
- burning of fossil fuels;
- exploitation of the motor transport.

The persistent pollution, which could not be destroyed collapse biologically, is of special significance. The term 'heavy metals' commonly denotes the metals, whose relative density is greater than 5 g/cm^3 and thus about 70, or seven-eighths of all the known metals are heavy metals. In the environmental protection, according to the use of metals in the economy and the severe danger of their compounds, more attention is paid only to certain heavy metals and non-metals, the effects of which may pose a threat to living organisms, such as arsenic (As), mercury (Hg), cadmium (Cd), selenium (Se), copper (Cu), zinc (Zn), chromium (Cr), nickel (Ni), lead (Pb), tin (Sn), antimony (Sb), bismuth (Bi), cobalt (Co).

Heavy metals enter the atmosphere as a result of a variety of pollution sources, and with time as a result of the wet and the dry deposition they land on the soil. It is estimated that in Europe annually 130 g/ha of Ni, 500 g/ha of Zn, 20 g/ha of Pb, 75 g/ha of C, 20 g/ha of Cr and 3.5 g/ha Cd land on the soil. Industrial activity, energy production and motor transport impact result in the increased concentrations of heavy metals in the upper soil layer on a global scale, as the soil has very high metal sorption capacity. Particularly high soil pollution is detected in cities, in surrounding areas of large industrial plants and along the highways. Each of the pollution sources depending on its type of activity, has a particular composition of chemical elements landing around it, formed by the chemical elements related to a fuel or the raw materials to be processed. Heavy metals enter the soil also due to agricultural activity. As the agricultural land is fertilized, limed and treated with pesticides, heavy metals accumulate in the upper layer of soil. Subsequently, many agricultural soils have high heavy metal content.

Soil contamination problems are caused by irrigation of agricultural land. The problem is particularly acute in the areas where the sewage water is used for watering of farmland. As a result, the soil is contaminated with Zn, Cu, Ni, Cr, Pb, Cd and Hg. Heavy metals are brought into the soil also with sewage sludge, which in many parts of the world is used to fertilize the agricultural and forest land. Therefore, Latvian and European Union law requires that before the use of sewage sludge as fertilizer, the soil and sewage sludge chemical composition analysis must be carried out.

However, the larger problem of groundwater contamination with heavy metals is caused by point sources of pollution:

- waste dumps;
- chemical product storage and transfer sites;
- industrial enterprises.

Heavy metals at high concentrations affect many processes in the soil:

- they inhibit the activity of microorganisms and thereby the circulation of nutrients in the soil;
- they have a toxic effect on plant roots, resulting in decreased nutrient intake.

As heavy metals reach the soil, they do not degrade, but slowly, with downward water flows, migrate deeper. The chemical elements in the soil participate in various chemical and biochemical reactions, creating new compounds, whose toxicity may increase in the soil. As the soil pollution increases over time, the risk of groundwater pollution with heavy metals rises.

Increased concentration of heavy metals in the soil significantly affects the plants and groundwater quality. Toxic concentration of microelements in soil and their effect on plants is a very complex issue, because it is influenced by a great number of factors.

9.3. Soil desertification and salinization

Soil degradation is one of the most important problems in the complex of problems connected with the processes of desertification. Soil degradation means decrease and loss of biological and economical productivity of arable lands and pastures, forests and timberlands under the influence of natural and anthropogenic factors. Natural and anthropogenic factors of soil degradation are tightly connected with large-scale development of soils in arid conditions. Processes of fertilization decrease, degradation and destruction of topsoil count thousands and hundreds of various local and zonal forms of display. Between them most widespread are regression grazing and overgrazing, formation of mobile sand dunes, surface runoff and irrigational soil erosion, contamination of soil with toxic compounds, technogenic desertification and other. 400 hectares or 10% of irrigated soil are in unsatisfactory condition (Figure pic. 9.8).

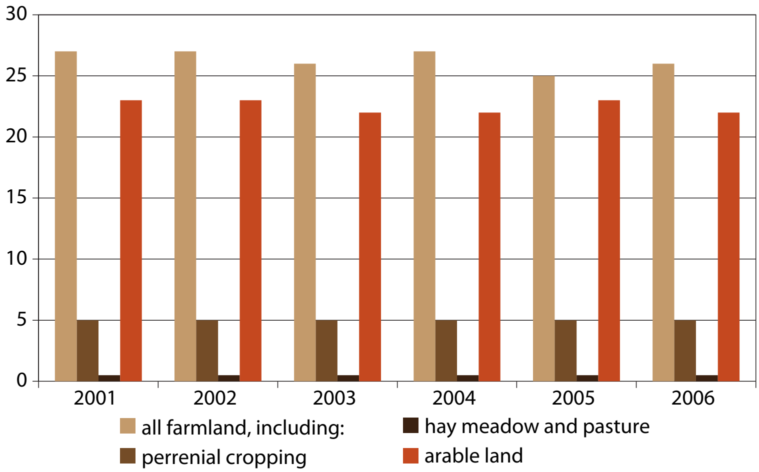


Figure 9.8. Structure of use of agricultural lands in Uzbekistan (th. km^2)

Desertification is land degradation in arid and semi-arid areas resulting from various factors including climatic conditions and human activity. Deserification affects the living conditions of rural people, who depend on livestock, crops, limited water resources and fuel wood. Desertification is the most actual problem for drylands (arid, semi-arid and dry sub-humid areas). In drylands desertification risks creates low, infrequent, irregular and unpredictable precipitation, large variations between day and night-time temperatures and low amounts of organic matter in soils. When land degradation happens in the drylands, it often creates desert-like conditions and can be defined as desertification. Desertification destroy elemental biogeochemical and biological cycles and have serious consequences for the environment. Desertification is caused by human activities, such as overgrazing, over-cultivation, deforestation and poorly planned irrigation systems as well as extreme climatic events, such as droughts. Desertification occurs because drylands are extremely vulnerable to over-exploitation and inappropriate land use, but the consequences are reduced food production, soil infertility, reduced water quality, sedimentation in rivers and lakes, and silting of reservoirs, aggravation of health problems due to wind-blown dust, including eye infections, respiratory illnesses, allergies, and mental stress, loss of acceptable living conditions.

Another major environmental problem is soil salinization in irrigated lands,as far as water from underground reservoirs is often polluted, but evaporation brings mineral salts to the surface, resulting in high salinity. Increased soil salinity makes the soil unsuitable for crops which cannot withstand high salt concentrations. In Uzbekistan saline soils compose 65.9% of irrigation area, including mild salted – 33.9%, salted – 19.4%, highly saline – 12.6%. At irrigation territory of Uzbekistan 8% of soil is subjected to irrigational erosion, 2% of them is in moderate and in severe measure.

In Uzbekistan around 50% of all irrigated soils are considered saline. Saline soils are widely spread in the Karakalpakstan, in Buhar, Navoji and Sirdarjensk region. Almost 5% of area of irrigated soil – 213.1 thousand hectares is noted as strongly saline.

More than a half of the areas located on alluvial plains suffer from salinity and excessive moisture. Salinity is not only a reason of irrigation, which is characteristic for all intermountain, alluvial and proluvial territories of arid zone. Main reasons of soil salinization is irrigation without drainage, huge water losses due to filtration, construction of irrigation channels without hydro isolation, excess of irrigation standards, uncontrollable water flow, irrigation with mineral water.

So, for example, annual increase of salts in irrigated salts of Karakalpakstan is 10-30 tons per hectare. With increase of salinity of irrigation water and soil the fertility level of crops is decreasing. So, for example, fertility of cotton in the last years has decreased in Khorezm region from 39-41 centner per hectare (c/hect) to 29-33 c/hect, and in Karakalpakstan from 30-34 c/hect to 14-24 c/hect.

Bibliography

Albert A. (1987) Xenobiosis. London: Chapman and Hall.

Darba vides riska faktori un strādājošo veselības aizsardzība (2001) (Red. V. Kaļķis, Ž. Roja), Rīga: Elpa.

Gemste I., Vucans A. (2002) Notekūdeņu dūņas un to izmantošana. Jelgava.

Kalniņa D. (2006) Nafta un vides problēmas. Rīga: Rīgas Tehniskā universitāte.

Kļaviņš M., Cimdiņš P. (2004) Ūdeņu kvalitāte un tās aizsardzība. Rīga: LU Akadēmiskais apgāds.

Marsh W. M., Grossa J. M. (1996) Environmental Geography. Science, Land Use, and Earth Systems. N.Y.: J. Wiley.

Nikodemus O., Kārkliņš A., Kļaviņš M., Melecis V. (2009) Augsnes ilgtspējīga izmantošana un aizsardzība. Rīga: LU.

Johnston J. J. (2000) Pesticides and Wildlife. Oxford: Oxford University Press.

Pazemes ūdeņu aizsardzība Latvijā. (1997) Rīga: LR VARAM.

UNESCO. (2008). Lerning to combat desertification – Teachers kit.

Desertification: a visual synthesis (2011) UNCCD, Zoi Environment Network.

Окружающая среда и безопасность в бассейне Амударьи. ЮНЕП, ПРООН, ЕЭК ООН, ОБСЕ, РЭЦ, НАТО. 2011. – 11 с. Accessible: *www.unep.org*.

Вода жизненно важный ресурс для будущего Узбекистана. Ташкент, ПРООН. 2007. – 128 с. Accessible: *www.undp.uz*.

Первое Национальное сообщение Республики Узбекистан по рамочной конвенции ООН об изменении климата. Ташкент 1999. – 110 с.; Второе национальное сообщение РУз по рамочной конвенции ООН об изменении климата. Ташкент 2008. – 205 с.

Национальный доклад о состоянии окружающей среды и использовании природных ресурсов в Республике Узбекистан (1988-2007). Госкомприроды. Ташкент, 2008. – 298 с. Accessible: *www.econews.uz*.

Экологический обзор Узбекистана, основанный на индикаторах. ПРООН, Госкомприроды РУз. Ташкент 2008. – 88 с.

Central Asia Atlas of natural resources. ADB. 2009. – 173 c.

Soil health. Accessible: *www.soilhealth.segs.uwa.edu.au/*.

Soil Biological Communities. Accessible: *www.blm.gov/nstc/soil/index.html*.

EEA – European Environment Agency, Copenhagen. Accessible: *www.eea.eu.int/*.

Land management and natural hazards. Accessible: *eusoils.jrc.ec.europa.eu/*.

ADB. (2011) Combating Desertification in Asia. Asian Development Bank. Accessible: *www.adb.org/environment/desertification.asp*.

10. INTERNATIONAL COOPERATION IN ENVIRONMENTAL PROTECTION AND SUSTAINABLE DEVELOPMENT

10.1. Mutual cooperation and development

According to the economist R. Norgaard, the development of a society can also be considered to be a common development of the systems of culture and ecology. He calls it a paradigm of common evolution and predicts that the progress and harmony of the development of different cultures in future will be determined by the potential of the 'patchwork' principle.

The concept of mutual cooperation and development was initially used in biology in relation to evolutionary interaction of two mutually connected species when typical genetic features determine a better fitness of one of the species; however, the dominating genetic features of this species leave a considerable impact on other species. Explaining the essence of mutual development, it is assumed that there is an interaction between the essential features or part of the features which then influence further evolution. Within the systems of common development the proportions may change unpredictably.

We can imagine the Baltic Sea Region, its countries forming a colourful patchwork quilt. The pieces hold well together in the southern and western parts of the Baltic Sea Region; however, the stitches appear looser in the direction from the east to the west. Each particular 'patch', e.g. Latvia, develops its culture and economy in its own way, while common development implies ties with the neighbouring countries, too. Besides, new ties are being formed with European Union Member States, and the earlier ties with the former Eastern block are retained.

Today the more developed countries jointly evolve, using the achievements of Western science and fossil hydrocarbon fuel (oil, natural gas and coal). People use the same or similar chemical fertilizers and pesticides for cultivating similar varieties of corn. However, the idea of common evolution should be based on the idea of sustainable development. Thus, it would be for the common benefit of all peoples, even if the development patterns of individual countries were different. Earlier cultural diversity was possible because individual cultures had more space; representatives of different cultures did not meet as frequently as today, and communities depended on their own resources, labour and technologies. The modern world is going through the process of globalisation: expansion of the market economy and advance of the developing countries towards the common market, thus facilitating an increasing uniformity in the world.

The 'patchwork' metaphor implies that the Baltic Sea coast countries should engage in a common development process, using their local knowledge accumulated over the centuries. By preserving the local specifics and cultural diversity in the modern and dynamic world, the countries of the Baltic Sea Region will be able to ensure sustainable development

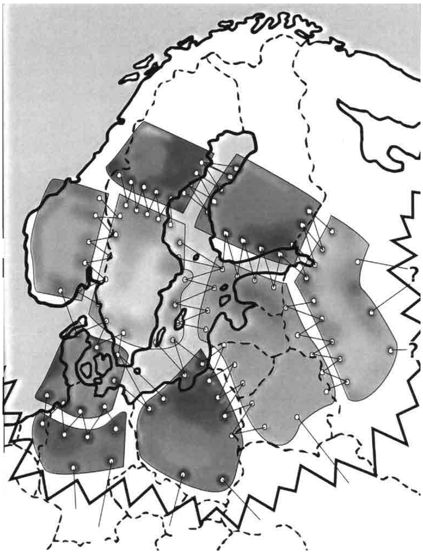


Figure 10.1. 'Patchwork' of the Baltic Sea Region

Knowledge, values, technologies and institutional structure – all of it is connected with a common environment in each particular country. Sustainability can be ensured only by considerate activities in each particular place. 'Traditional knowledge has local peculiarities that have evolved as a result of a unique common development of particular social and ecological systems,' says D. Orr. Sustainability should be based on not only revival and preservation of traditional knowledge in each country and in the 'patchwork' countries, but also on exchange of knowledge on a much larger scale – not only within the Baltic Sea Region but also within the European Union and worldwide.

However, ever fewer languages are used on intercontinental flights, mobile telephones and the Internet. If fast-food restaurants and supermarkets take over the market of corner shops and small cafés, is this a road to sustainability? Is the road of sustainable development secured if we all speak, although some difficulty, one language and eat the same food (with minor local differences)?

The metaphor of the 'patchwork quilt' is based on the idea that all countries around the Baltic Sea have been historically closely interconnected and their application of the local knowledge has ensured their centuries-long success. They are not afraid or shy to be distinctive and different. The preservation of local peculiarities and cultural diversity in a dynamic and unevenly changing world could be an important feature of sustainable development in the Baltic Sea Region.

10.2. International environmental issues

Many environmental issues are of an international character, at times becoming global in a political sense as they involve larger territories than the frontiers of countries mark. This refers to such major environmental systems like the Earth's atmosphere and the World Ocean; nevertheless, scientifically speaking, the biosphere, too, is common for the whole of the world. Although it is divided into the ecosystems of different countries, the loss of balance within an individual ecosystem may have a negative impact on other ecosystems and even entail risks to the existence of the biosphere. It also causes problems in international relations since sovereign states are rather biased when defending their independence and caring for the quality of their environment and natural resources. Thus, individual countries are guided by their interests in assessment of international environmental issues and their solutions.

In some cases – climate change, ozone depletion, trade in endangered species – the principles of environmental protection are logical and internationally imperative. In other cases complications arise, for example, concerning transportation of toxic waste across borders. Since globally the amount of toxic waste is rapidly increasing, it seems plausible that there are many countries which cannot afford building safe toxic waste recycling enterprises and landfills, which is why toxic waste is transported to other countries. However, the UN stand on this issue is unequivocal: the disposal of toxic waste in developing countries, as practised by developed countries, should be banned.

The most important global environmental issues concern the atmosphere, especially climate change and excessive catch in the World Ocean. They are truly issues of the whole of humanity since everybody uses the air and resources of the sea. The prospective exploitation of the Antarctica also belongs to these issues, as everybody might benefit from it.

G. Hardin proposed the metaphor of 'the tragedy of the commons' because such world natural resources are very sensitive to overuse or pollution. Nobody owns these resources – neither an individual state nor a corporation nor a physical person. This explains the fact that no restrictions have been imposed: there are no private property borders or exploitation quotas. Consequently, everybody can go on exploiting the commons for one's needs up to the depletion of the resource or the collapse of the system. Any country may emit an unlimited amount of greenhouse gasses into the atmosphere or deplete all the fish in a particular fishing area.

As a result, the common resources are being depleted at an alarming rate. The tragedy, according to G. Hardin, is inevitable since the world resource reserves, limited as they are, are being devastated. He compares the problem to a lifeboat: 'We cannot have everybody on board the lifeboat because there are a limited number of seats.' To avoid such a tragedy, each individual must support the implementation of an authoritative management of the common resources. Hardin proposes to appoint a leader who would see to the exploitation quotas.

Doubtlessly, the society must take it into consideration and make provisions for preservation of these common resources. However, it is a complicated international task for there are too many culprits

According to the classification of the United Nations Environmental Programme (UNEP), the quality of environment and its trends of change can be divided into four categories:

- atmosphere (climate, ozone depletion, air pollution – local or transboundary),
- water (inland, coastal and sea ecosystems),
- earth (forests, desertification, use of land, soil),
- biological diversity.

Considering the complex nature of international diplomatic relations, attempts are being made to distinguish global and transboundary environmental issues, or to seek solutions for global and transboundary issues separately.

as well as victims, and it is difficult to determine their respective responsibilities and duties. At present the only solution is to reach an international agreement and adopt international binding multilateral treaties.

The prospective exploitation of the Antarctica is also considered a problem of common environmental significance as many might benefit from it. Territorial claims to the Antarctica are being contested although they are not adjudicated because the Antarctic Treaty of 1959 is still in force. This international treaty obligates the signatory countries to preserve the Antarctica and the surrounding seas south of 60° S latitude free for scientific research to any country of the world. The Treaty established this territory as a demilitarised zone free of nuclear weapons, also stipulating measures of nature and environmental protection.

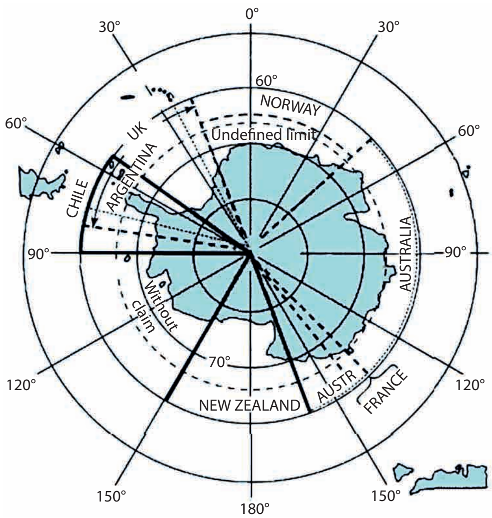


Figure 10.2. Potential territorial claims of the countries to the Antarctica

While the Antarctic Treaty was still relatively flexible, it was under considerable pressure since there was an immense interest in the exploitation of the resources (oil, industrial minerals, shrimp, fish). This conflicted with the environmental protection demands. Today increasingly pressing demands are being voiced to modify the Antarctic Treaty, coming from non-member countries as well (in fact, these countries are not able to carry out any essential scientific research on the territory of the Antarctica). Non-governmental organisations, too, call for UN mediation to transfer the control over the Antarctica to all countries of the world, not just the member states of the Treaty. There are certain tendencies that might lead to the mitigation of the 1988 Convention on the Regulation of Antarctic

Mineral Resources. Up to now the Convention stipulates that the use of mineral resources might be permissible only upon a very rigid evaluation of the impact on the environment which is confirmed by the member states of the Convention. The conflict between the United Kingdom and Argentina over the Falkland Islands was a clear warning that the lucrative Antarctic mineral resources may call forth territorial claims.

As a measure of the World Ocean protection, the 1954 International Convention on the Prevention of Pollution of the Sea by Oil was adopted to minimise the discharge of oil and oil waste from tankers and other vessels. To secure the efficiency of the protection of oceanic waters, it was necessary to adopt restrictions on pollution of rivers, on wastewater, air pollution since these types of pollution also lead to the pollution of the ocean.

In 1958, the first conference on the Maritime Law took place, but in 1959 the UN established the International Maritime Organisation, which was entrusted with the improvement of security measures at sea, facilitation of the development of regulations and decreasing of pollution.

In the early 1970s maritime countries began declaring their coastal waters part of their jurisdiction on an increasingly larger scale. First, it was 3 nautical miles, then 12 and now even 200 nautical miles.

However, the 1950 Convention on the Continental Shelf was less ambitious although with time there was a growing interest in shelf resources. To tackle these issues, the Third Conference on the Maritime Law was held in 1974.

The Regional Seas Subprogramme of the UN Environment Programme brought together maritime countries to discuss the situation. The conference resulted in a number of regional maritime agreements that referred to the Mediterranean, the Persian Gulf, the Western Africa region, South-East of the Pacific, the Red Sea, seas of Eastern Africa and South Pacific. These agreements laid the foundation for environmental action plans and cooperation towards reduction of pollution.

In 1977, the North Sea ceased to exist as an open sea as fishing and extraction of mineral resources was restricted when the European Union determined the new zoning of the continental shelf. Thus, the North Sea as well as the Sea of Japan, the Baltic Sea and the Mediterranean became subjects of conventions or international agreements. The UN also set additional demands regarding the territories of these seas to ensure an effective control of pollution.

The 1982 conference in Jamaica adopted the Convention on the Maritime Law, stipulating that the Convention refers to the areas up to the depth of 2500 m from the shore.

In the late 1960s, researchers identified a hazardous and growing water pollution and reduction of the oxygen concentration in the Baltic Sea. All the seven Baltic Sea states – Denmark, Finland, the Democratic Republic of Germany, the Federative Republic of Germany, Poland, Sweden and the USSR – agreed on taking immediate measures to reduce the pollution of the sea. The Convention on the Protection of the Marine Environment of the Baltic Sea Area was adopted in 1974. Within its framework, the Helsinki Commission (HELCOM) was established to ensure the implementation, monitoring and development of a programme of common activities. At the time it was a unique attempt to agree on cooperation in addressing common environmental problems in East European and West European countries simultaneously. In this way cooperation ties were established for joint efforts towards measures for environmental protection and general security.

Figure 10.3. Shipwreck of the tanker *Amoco Cadiz* off the coast of Brittany (France) on 16 March 1978

In 1984, during the first meeting of the ministers of the Baltic Sea Region countries, an action plan was adopted concerning four spheres: reduction of pollution, scientific research, navigation safety and prevention of oil leakage. The plan could be viewed as a political support for the development of the scientific and technological strategy. Solutions for problems of national character or implementation of projects were not discussed, neither were any binding documents adopted. In the second meeting of the ministers, in 1988, 78 projects were endorsed although many important problems were left unresolved. Much criticism was levelled at no tangible progress, and demands were made for actual measures and concrete results.

On the whole, many developing countries wished to see the World Ocean as a free-for-all territory, like the Antarctica, rather than have the huge area *de facto* taken over by the states which had the most up-to-date technology for exploiting the oceanic resources at their disposal.

A common tendency can be traced in the conventions adopted and treaties signed: to allot an increasingly significant place to the principle of precaution. The countries of the world are called upon to prevent pollution in case of emergency situations and accidents. Such policy was caused by the catastrophic accident in Chernobyl, on the tanker *Amoco Cadiz* and similar cases.

10.3. Institutions involved in international environmental protection

In accordance with the principal theoretical concepts concerning international relations, states undertake international cooperation only if there is any prospective benefit for their countries otherwise unachievable. In fact, countries desire to reap maximum benefit from international cooperation compared to other countries irrespective of their status in the international convention of countries. On individual occasions states can hope for some indirect benefit, for example, by promoting good international relations with other countries. However, a higher level of socialisation and friendliness are highly appreciated, which makes it possible to claim a larger portion of the common world reserves. Sometimes countries, in the name of their interests, make rather blatant attempts at a profitable bargain, even at the expense of other countries – by asking an inflated price for their participation, inadequate compared to the real potential of the respective state.

Different conceptual approaches, national interests, the level of own responsibility and abilities, as well as the efficiency of work become essential elements in the development, adoption and implementation of multilateral international agreements.

Governments establish various executive institutions, including environmental agencies. They are exposed to different kinds of pressure from the local entrepreneurs or businesses who would like to enjoy certain privileges or benefits related to the exploitation of natural resources or environmental pollution. At times these pressures make a government present itself in the international arena less as an environmental problem solver but more as a petitioner, which can leave a considerable impact on the environmental efforts of other countries, to the point of rejecting otherwise necessary solutions.

In many cases, individual ministries or even agencies represent their countries in international work groups or meetings, and on certain issues they may hold views that differ from those of the country. Sometimes the official state delegations find themselves under pressure – on the basis of their democratic rights, local interest groups (producers or active environmentalists) seek to attain an internationally binding decision that would benefit them. Besides, decision-makers need to consider general public sentiments as well.

States of the world are very different, have different historical heritage, environmental conditions and natural resource reserves. Some countries can be considered advocates of the modern environmental protection ideas. They include Europe's Nordic countries, which pursue strict demands in the sphere of international environmental

The number of institutions and persons involved in international environmental protection is very large; however, by an attempt to group them, the most significant units are:

- states,
- international environmental organisations,
- global environmental movements,
- industry and business,
- experts,
- society at large,
- individual talented personalities.

Of all the above-mentioned, it is only governments, or states they represent, that have the right to take internationally binding decisions. Only governments of sovereign states can ensure participation of their citizens in the implementation of international regulations. It is the states that manage the use of their resources for economic development or military aims; moreover, by using their political rights, they ensure that the welfare and social goals of their people are attained.

management and protection, call on other states to participate in discussions and even take on unilateral additional obligations to encourage other countries and peoples to follow suit.

The European Union also supports a more rigorous international management of environment by allotting considerable funds for this aim. However, with the EU expansion, differences in the opinions on the future perspective can be observed among member states.

The position of the USA on environmental problems of global significance, especially on restricting climate change and a tougher international management of environment, has been severely criticised.

Nevertheless, several blocks of similarly thinking countries have formed. The 'northern' block includes the industrialised welfare states of North America, Europe and other continents. The 'southern' block is larger, represented by the developing countries of Asia, South America and Africa. The former Second World (socialist) countries together with the South-East Asian countries form the block of the developing countries. The situation in the 'Fourth World' countries (mostly African) is the gravest. These states suffer from extreme poverty, wars, unrests, diseases, lack of food and social care. The block of developing countries has grown from 77 states (G77) to 130 states, and it has a significant proportion of say in making international decisions.

The 'northern' block focuses more on such environmental problems as climate change and ozone depletion, whereas the priorities of the 'southern' block are the lack of drinking water and desertification.

Of great importance are the funds that have been used to attain the aims of environmental policy. Individual countries have a significant influence on which problems are raised for discussion, on negotiations and making political decisions, signing conventions and protocols. Sometimes a group of countries united by common interests, international organisations or even talented and purpose-driven individuals assume the role of the leader in negotiations. Leaders should be distinctly positive to be able to steer countries towards adopting more rigorous demands for the preservation of the global environment. There are also countries which, due to different reasons, oppose the treatment of a particular environmental issue; several countries which share such a stand can form a 'veto coalition' and sometimes achieve that the issue is removed from the international environmental political agenda.

A situation like this has developed around the preparation of an international document concerning the protection of whales: Iceland, Norway and Japan are strictly against imposing a moratorium on whale hunt. Similarly, the exporting countries of genetically modified corn – Canada, the USA, Argentina – weakened the Cartagena Protocol on Biosafety to the Convention on Biological Diversity, which came into force in 2003.

However, sometimes groups of countries can achieve imposition of stricter demands, like in the case of the Basel Convention, when African countries called for a total ban on transporting toxic waste from the countries of the 'northern' block to the countries of the 'southern' block. African countries had the crucial role in the development of the Convention to Combat Desertification.

10.3.1. International environmental organisations

In the majority of cases, international environmental organisations have been set up by mutual agreement of countries for practical measures to tackle global environmental issues. International environmental organisations have been extremely good at organising broad discussions to prepare projects of environmental policy planning, funding and implementation. At present there are about 250 international environmental organisations, most of them specialising in preparation and implementation of conventions on both global and local scale. The origins of environmental organisations date back to the time after World War II when the world faced the necessity to create a system to prevent wars, to restore the demolished economies and prepare solid ground for successful development. Thus, the United Nations (UN) was established, as well as the International Bank of Reconstruction and Development (the World Bank) and the International Monetary Fund. The General Agreement on Tariffs and Trade (GATT) later became the World Trade Organisation.

Several massive regional organisations came into being: the European Union, the North American Free Trade Association (NAFTA) and the Association of South East Asian Nations (ASEAN). All these organisations play an important role in tackling global environmental issues up to this day.

Figure 10.4. Signing of the UN Charter (26 June 1945, San Francisco, USA)

Figure 10.5. UN Headquarters in New York, USA

However, the leading role belongs to the UN and its environmental organisations. The UN was founded in October 1945, when 50 countries signed the UN Charter in San Francisco, the USA. Today the number of its member states has grown to 192, and the UN is recognised as the world's most influential international organisation. Its initial task was to promote peace in the world, prevent conflicts between states, control armament, protect human rights, facilitate economic and social development and preserve the global environment.

To accomplish the tasks regarding the environment and development, the UN has set up the following programmes: the United Nations Environment Programme (UNEP), the United Nations Development Programme (UNDP) as well as the Commission on Sustainable Development (CSD). These organisations work under the auspices of the UN Secretariat, but their budget is endorsed by the General Assembly of the UN.

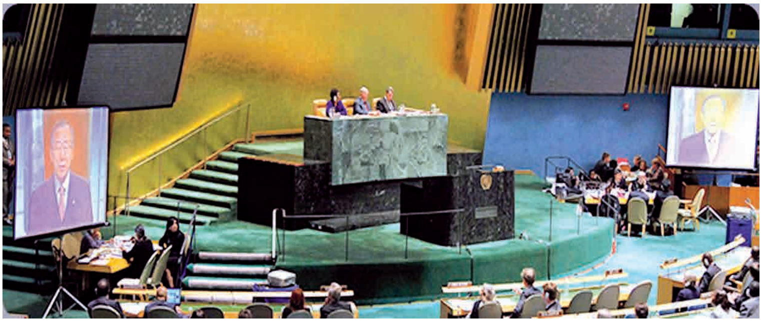


Figure 10.6. UN Assembly Hall

The speaker is Ban Ki-Moon from South Korea, who assumed office as the Secretary General of UN on 1 January 2007.

The necessity of the UN Environment Programme was confirmed during the United Nations Conference on the Human Environment in Stockholm in 1972 as a response to the signals of the alarming deterioration of the quality of the environment. The headquarters of the UN Environment Programme is in Nairobi, Kenya, but there are also offices in Switzerland (Geneva) and other countries. Among the tasks of the Programme are: the control of the fulfilment of international agreements and decisions on environmental issues; urging discussions on new initiatives of environmental protection, also by aggregating environment-related information from the countries of the world and by rendering support for the required scientific research.

Together with the UN Development Programme and the World Bank, the UN Environment Programme maintains the Global Environment Facility (GEF), which, in turn, funds projects that tackle the most topical environmental issues.

UNEP

Figure 10.7. Emblem of the UN Environment Programme

However, the possibilities of the UN Environment Programme are rather limited. Therefore, the countries of the world deliberate on substitution of the Programme with the Global Environment Organisation (GEO), which would have wider powers and better funding.

10.3.2. Environmental activist groups

Environmental activist groups usually come out against slow and low-quality measures aimed at tackling environmental issues, and they often attract the attention of the society to lesser-known environmental issues. Thus, they present an important force in the global environmental management. There are numerous environmental activist groups and they have different interests because of their differences in ideology, strategy, institutional structure and goals.

Global environmental protection groups have manifested themselves to the world in various ways. Their principal activities are aimed at global protection of the environment. Among these groups are the World Wide Fund for Nature (WWF), Greenpeace and the Climate Change Network. Some organisations specialise in data collection that testify to the degradation of the world's environment, for example, the World Resources Institute in Washington prepares regular surveys of all kinds of impact on the environment caused by anthropogenic activities.

Figure 10.8. Greenpeace protests against the company Esso/Exxon Mobil

Many environmentalist groups are extremely active at the venues of important negotiations on the problems of the world's environment or sustainable development and also at world environmental congresses. The protesters often wear masks of animals or birds, stick up protest slogans on tall buildings, and actively lobby leaders of official delegations or delegates. Of late they also organise parallel conferences and environmental forums.

Such activities cannot be ignored, especially because the majority of the society support the environmentalist groups and take their side. Consequently, many protesters' demands are included in official agendas and even reflected in the concluding documents. There are new tendencies that global environmentalist groups cooperate and work out alternative concluding documents, make them known to wide public, collect signatures in support of such documents and demand their consideration along with the official concluding documents. For example, the International Union for the Conservation of Nature (IUCN), consisting of a network of nature protection groups, prepared the Draft Convention on Biodiversity.

Participation of environmentalist groups in the implementation of international conventions and decisions as well as monitoring is of great importance. Usually these issues are within the competence of member states; however, the states not always have the necessary potential and funds. Therefore, environmentalist groups enjoy strong support. They raise the alarm if their countries do not fulfil their international duties or their activities fail to meet the requirements of the international documents they have signed and ratified.

The global society has a decisive role in all future processes, including environmental protection and sustainable development; nevertheless, the political process is being steered precisely towards the needs of the population of the world. The global and local groups of environmental protection have also come from the grassroots to demonstrate public discontent with environmental degradation, and their activities facilitate dissemination of democratic principles in the society as well as public participation in the management of the global environment.

10.3.3. International corporations

The world economic system, which includes individual enterprises, companies, joint-stock companies and international corporations, exploits natural resources, and the result is environmental pollution. This is a cause of constant complications and even conflicts between economic development and environmental protection. It is widely believed that it is the large corporations, exercising a disproportionate influence on political processes, that should be held responsible for the current degradation of the environment and depletion of the world resources. At the same time, corporations and the business world make efforts to diminish their negative impact on the environment by working out and implementing standards of good management practice; they also attempt to present themselves to the society in a 'greener' light.

However, facts show that there is a close connection between sectors of industry and global environmental issues.

The industry and service sectors have great influence not only on the environment but also on the respective national governments and the development of their policies and development plans. However, large companies seldom get directly involved in politics. Usually this is the sphere of specific non-governmental organisations connected with industry and trade. One such major organisation is the World Business Council for Sustainable Development (WBCSD), representing over 170 sectors of industry. This organisation was founded in 1991, shortly before the UN Conference on Environment and Development, to summarise and publicise the opinion of the business world on future tendencies.

The International Chamber of Commerce (ICC) also integrates different and diverse organisations to join in the discussions on international environmental issues.

The activities of organisations for international environmental management include participation in global environmental forums or lobbying in their own countries. Sometimes organisations try to influence governments as they participate in the drafting of international regulations or standards to corner the market for their goods or services as well as to secure other advantages and increase their capacity to compete in global markets.

In many cases the industry and trade sectors want to achieve adoption of universal international standards in order to exclude competitors.

It is noteworthy that tackling many global environmental issues is even unfeasible without drawing in the industry and trade sectors, principally in relation to environmental pollution which underlies unwelcome climate changes and ozone depletion. Many sectors feel under threat as they are found co-responsible for causing environmental problems; others are ready to offer solutions along with reaping huge profits for themselves.

Undeniably, producers have an increasingly powerful say not only in the development of the environmental policy in their countries but also in the development of a new kind of relations with the public. Voluntary commitments concerning environment-friendly production and an appropriate mechanism of control of certification and compliance featuring distinct eco-labelling win public acclaim.

Table 10.1. Global environmental issues and the associated sectors of industry

Global environmental issue	*Primary production*	*Secondary use*
Climate change	Extraction of fossil fuel	Energy production, provision of transport system
Flow of toxic waste	Waste recovery and disposal	Use of recycled materials
Decrease in biodiversity and biosafety	Agricultural, biotechnological and pharmaceutical industries	Use of mineral fertilizers, pesticides and modified organisms in farms
Ozone depletion	Chemical industry	Production of refrigerators, electronic goods and aerosols
Spread of stable organic compounds	Chemical industry	Agriculture
Decrease in forest areas	Chemical and forestry industry	Timber industry
Pollution of the World Ocean	Oil extraction and transportation	Sectors that use oil products

10.4. Role of science and scientists in identification and tackling of environmental problems

Scientists definitely play a prominent role in the development of international documents pertaining to environmental policy. Although it was traditionally believed that scientists were not directly involved in the process, the UN Conference on the Human Environment in Stockholm, 1972, actually brought out their special role.

At the intellectual level, problems are identified and scientifically described. In this regard, J. Evelyn's research is notable; he announced that the quality of air in London was poor in a publication in 1661. Similarly, the French engineer Jean-Antoine Fabre (1748-1834), after having carried out research in the mountains, informed the public about soil erosion in the Alps.

Figure 10.9. The Swedish chemist Svante Oden (1924-1986) was the first to study the consequences of burning fossil fuel

He realised that sulphurous compounds in fuel can be oxidised in the process of burning and later might turn into sulphuric acid, which has a devastating impact on the environment. It was tested by the International Meteorological Institute in Stockholm, which since the 1950s has carried out measuring of atmospheric pollution.

J. A. Fabre's observations concerning soil erosion did not offer solutions to the problem. The same can be said about the talented and versatile polyglot George Perkins Marsh, ambassador of the USA to Italy, who in his book *Man and Nature* (1864) explained, in the scope of contemporary knowledge, the role of rivers, banks and surrounding wetlands in the origin of floods in continental Europe. He predicted the possibility of floods as long as humans would continue industrialising and adapting rivers to their needs. However, he did not solve the problem either.

In the early 20th century, the Swedish scientist Einar Naumann explained the principles of eutrophication. He discovered that an excessive amount of nitrates and phosphates causes biological activity. The results turned out to be correct although no one gave careful attention to them until the problem gained topicality in connection with a massive loss of fish. Consequently, scientific research was necessary, yet it had been insufficient.

Speaking of scientists as discoverers of problems, the name of the Swedish chemist Svante Oden (1924-1986) is often mentioned. He discovered the complex and large-scale acidification mechanism and studied it in relation to burning fossil fuels. Indeed, for about a century scientists had had some general knowledge on it, but S. Oden's article, which was published in the Swedish newspaper *Dagens Nyheter* in 1967, turned out pivotal in tackling the situation in practice. The novelty was the more recent and precise data; yet most importantly, this information could be introduced to politicians who used it in decision-making. As a result, the concept of environmental protection was worked out in the 1960s, and practical tasks were outlined. 'Acid precipitation' became an issue to be discussed in political circles, but the problem formulated by S. Oden became an environmental problem as well.

In the 19th century, global warming had not yet become an environmental problem. However, there were scientists who saw a link between the temperature rise and human activity. Svante Arrhenius (1859-1927), a physico-chemist at the Stockholm Högskola, had put forward the theory of the greenhouse effect already in 1896, but in 1938 the British scientist Guy Stewart Callendar (1898-1964) published an article in which he demonstrated a connection between this phenomenon and burning of fossil fuel. As a result of burning, carbon dioxide is emitted, and with its concentration in the atmosphere rising, the air temperature also rises. However, even G. S. Callendar himself did not consider that to constitute an environmental problem because it was not socially recognised. It did not gain recognition up to 1960 when the concept of the greenhouse effect was already in wide use and the global temperature rise had become a topical environmental problem. The process of global warming was gradually progressing, and the problem had to be included in the programme of human activity.

Environmental problems are not new, they have existed for hundreds of years and have arise in many places of the world. Yet they have been problems of local importance, dispersed and isolated in both time and space. They have emerged in various places and evaluated as well as tackled differently – by individuals and by society at large. Scientists and government officials have been involved, but sometimes these problems were left untreated, as was the case of the London smog. Londoners had complained about it already in the 13th century, but practical measures were taken only in the 1950s – 700 years later.

When these social problems surfaced and were explained, their nature changed. People's inconsiderate attitude to their environment was reflected in these problems. Along with the idea of the possibilities of nature and opportunities of environmental protection, a convincing interpretation method was created and introduced to journalists, scientists, international organisations and individuals concerned about environmental problems. Scientists created environmental models, concepts and theories; to the general public, scientists were the activators of environmental problems; it was only scientists who could use their methods to identify the borderline between what was 'normal' and 'problematic'.

The scientist as a discoverer of environmental problems performs other important functions in the modern society. The scientist is a teacher who disseminates knowledge on research and thus carries out the mission of educating the public about the questions of nature and the environment. The scientist is also a consultant who helps decision-makers to prepare optimum solutions; as a creator of new knowledge, the scientist works out the best

Figure 10.10. Major contribution of the outstanding Swedish chemist Svante Arrhenius (1859-1927) to science was his electrolytic dissociation theory

However, Arrhenius was a pioneer in many different spheres. Already in 1896 he had advanced the theory that the rise of carbon dioxide concentration in the atmosphere was going to cause the effect of global warming. He may have got interested in this problem after it was widely discussed in relation to the discovery of the recent Ice Age. He calculated that doubled concentration of carbon dioxide would result in a temperature rise by five degrees. His calculations are very close to our present-day notions.

technical and social solutions for the problems of nature and the environment. The scientist also assumes the role of a responsible intellectual by entering discussions and explaining the interrelation between environmental and political issues in the mass media.

Application and scientific interpretation of data on the environment are instrumental in assessing global tendencies and developing future tendencies. The case of the Danish scientist Bjorn Lomborg is an enlightening example. In 2001 he published the book *The Skeptical Environmentalist* to prove that the existing state of the environment was not as bad as other scientists found it. Lomborg was severely criticised for a methodologically unjustified selection of separate environmental data to draw general conclusions inconsistent with the reality. However, he was not the only one to take a stand against the propagators of environmental problems. Such has been the case with the problem of ozone depletion, the currently topical climate warming and other issues. This urges the environmentalists to work even more assiduously and consider the complex and intricate nature of the phenomenon as well as be better prepared for the eventual attacks by sceptics and critics.

Science can take pride in being the driving force behind activity programs for nature and environmental protection. However, its history has not been a linear process, clearly outlined and progressive. It has rather been a meandering advance, with numerous attempts, failures and the significant achievements of the second half of the 20th century in creating models of nature and the environment. Science is also responsible for huge disasters, including harm to nature; yet future without science in inconceivable. Science remains a consequential factor in tackling problems of nature and the environment the humanity faces worldwide and in the Baltic Sea Region in particular.

10.5. Development of international cooperation

Policy of environmental protection (at least in its first stages) has been directed towards specific events. It is easy to attract the attention of the public by pointing out obvious and easily comprehensible problems such as acid rains, seal hunting in order to obtain furs and pollution caused by pesticides. However, when it comes to problems that become evident after a longer period of time, such as the global changes of temperature, expansion of deserts and depletion of biological diversity, it is considerably more difficult. The point of view of scientists regarding critical and problematic issues does not always coincide with that of the governments and international organisations.

For a government, an issue becomes critical only when it has attracted the attention of a great part of the public, its more prominent members, or when the attention of the mass media has also been attracted. That is why the international policy of environmental protection is concerned both with the growth of the movement of environmental protection and the development of scientific thought regarding important ecological processes. The 20th century has seen the most achievements of this kind.

In international political relations, the emergence of environmental protection issues as problems can be divided into four phases. The first phase began in the 19th century with the signing of bilateral fishery agreements and ended in 1945 when new international organisations were established. The second phase began with the foundation of the United Nations and reached its peak during the United Nations Conference on the Human Environment in Stockholm, 1972; the development and establishment of the movement of environmental protection took place during this phase. The third phase (1972-1992) witnessed an explosion of new environmental protection institutions and agreements. The fourth phase began with the United Nations Conference on the Environment and Development in Rio de Janeiro in 1992. The last phase is markedly characterised by integration of environmental issues in nearly all public and private spheres, and the impact of these issues on the activities of the humankind.

10.5.1. First phase: sea resources

In the beginning international environmental protection focused on systematising the issues of jurisdiction and ensuring the administration of international watercourses by passing laws for transboundary rivers and lakes. Attention was drawn to the populations of migrating wildlife as well due to the fact that no state could single-handedly take care of its protection when the growth of industry threatened to destroy many species; for example, the government of Switzerland proposed (albeit unsuccessfully) a formation of an international committee to protect migratory birds of Europe as early as in 1872. However, different governments had begun taking measures to protect nature even earlier than that; they were mostly to do with the interests of local economies – protection of forests, inland waters, mineral fields and certain wildlife species.

With the exception of the seal protection treaty (adopted in 1911), all the other early attempts to regulate the use of joint natural resources required so much debate that in the end they turned out to be inefficient and had to be postponed. Dealing with environmental problems was difficult due to the fact that there was no clearly defined ground and strict political approach; moreover, there were cultural differences, and all the aforementioned aspects led to different approaches. The attempt to ensure international whale protection turned out to be an especially unavailing episode in the history of international environmental protection. The Convention on Restrictions of Whaling was signed in Geneva in 1931, and 24 states had either ratified or joined it up to 1935. However, the Soviet Union and Japan – the two states most involved with whaling – did not sign the convention. In addition, the states that had signed the document had few duties to attend to. The International Whaling Commission was established in 1946 due to the initiative of the USA; a whaling code was adopted, and the commission could make amendments without holding official conferences. Yet, despite the authority given to the commission, the short-term interests of whaling were impossible to overcome, and the commission did not heed even its scientific advisors.

During the Conference on the Human Environment, whales were mentioned as a symbol of the antiecological behaviour of humans. A procession was organised for the protection of whales and a decision was passed to recommend a 10-year moratorium on commercial whaling, which was supposed to enhance the activities of the International Whaling Commission; yet it took 10 more years to authorise the moratorium.

The North Pacific Fur Seal Convention managed to protect seals from a direct impact of human activities by providing that hunting as well as the population of seals both on land and sea territories were to be controlled. In this case, international cooperation was more successful because the fur seals are a particular subspecies whose behaviour is easily predictable – they have localised territories for breeding their young; thus, the territories can be controlled by the state governments. Whales, on the other hand, have different subspecies that populate different oceans; their behaviour is not easily predictable, resulting in difficulties to determine their numbers and regulate the size of the population. The differences in political, economic and geographical factors only contributed to complications of the process.

Nevertheless, in 1982 the International Whaling Commission finally voted for halting commercial whaling, setting a period of transition of three years. The states concerned with whaling – Japan, the USSR, Brazil, Peru, Norway, Iceland and North Korea – still opposed the vote. However, in 1990, when the five-year moratorium had ended, in a conference held by the International Whaling Commission, most of the members voted to prolong the moratorium. The states against it accepted the vote since refusing to do so would have cost them their political and business reputation.

10.5.2. Second phase: activities of the environmental protection movement and the united nations

Many non-governmental organisations concerned with protection of the environment came into being after the end of World War II, supported by the governments on both national and international scale. During that time the global problems were related to four important spheres:

1) the ban on distribution of nuclear, biological and chemical weapons, reduction of military costs, and prevention of a new war,
2) reduction of poverty,
3) the nature and environment crisis that manifested itself in depletion of resources and biological diversity and in increasing amounts of waste,
4) recognition and ensuring of human rights.

However, the events that took place on an international scale had different impact regarding the social and environmental protection movement in each state based on the national political culture. For example, the environmental protection movements in Denmark, Sweden and the Netherlands had certain national peculiarities resulting from specialisation and the professional standard.

Some of the movements had attracted a great number of members whereas others consisted of a small number of groups of experts; similarly, some of the movements were concerned with solving general problems of environmental protection and development while others focused on particular environmental issues.

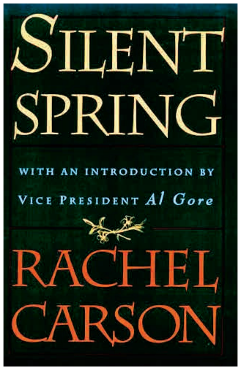
During the 60s, there was a significant interest in nature in scientific and economic aspects; the decade left an impact on how environmental problems were viewed in intellectual and political circles.

In 1962, Rachel Carson published her book *Silent Spring* which criticised the overly extensive use of pesticides and stressed their negative influence on human health and ecosystems. Although the scientific community criticised the work as being over-emotional, almost all of the pesticides mentioned by R. Carson are banned now.

In 1962, the actual state of environment was uncertain; however, 1970 arrived with a many-voiced and unyielding public opinion. Groups of concerned scientists, administrators and environmental protection enthusiasts initiated an explosion of a mass movement, which spread in the industrialised world. The later movement of environmental protection came more from the grassroots, was much more active and politically responsive compared to the earlier organisations of nature protection.

Significance of environmental organisations in the international relations of environmental protection begun to increase. Environmental organisations increased pressure on the governments to make them formulate and carry out efficient environmental protection

Figure 10.11. Rachel Louise Carson (1907-1964), a marine biologist and writer



Her most significant work is *Silent Spring,* republished in 2002 to commemorate 30 years since the publication of the first edition policies. Non-governmental organisations collaborated via a regional and global network in order to obtain information and work out the strategy needed for environmental protection. On the local scale the organisations established groups and enlisted individuals to solve particular immediate problems in their vicinity. These organisations were grassroots movements with influence on the international policy of environmental protection, and several organisations of significant standing and a particularly scientific or professional approach, such as the International Council of Scientific Unions and the World Conservation Union, grew out of them. They actively participated in the preparation of the United Nations Conference on the Human Environment in Stockholm, 1972.

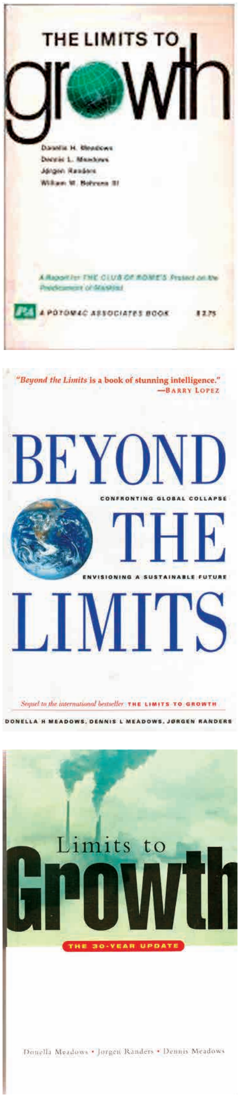


Figure 10.12. Three editions of *Limits to Growth* (1972, 1992 and 2004)

Among the institutions and centres concerned with environmental information, education and consultations, the International Institute for Environment and Development, the Institute for European Environmental Policy and the World Resources Institute stand out.

During the 50s and 60s, the global economy experienced growth; however, afterwards fundamental problems began to develop, resulting in the oil crisis of 1973. The crisis coincided with the awareness of the 'limits to growth', explained to the world by the Club of Rome.

The Club of Rome was established as a free association of European scientists, technical employees and politicians during the time when the liberal democracy of capitalism was shaken by crises, and issues of civil rights, peace and environment were beginning to dominate. The Club of Rome published the report *Limits to Growth*, based on the research carried out by the Massachusetts Institute of Technology (USA) led by D. Meadows.

Limits to Growth was based on the outcomes of prognoses regarding the constant depletion of resources, increase in pollution and population. The goal of the report was to promote awareness of the economic, political, social and environmental components of the global system as well as to aid the development of new opinions regarding the political means of solving problems. *Limits to Growth* exposed the probable global development up to 2100, examined the use of computer-created models in system analysis (which had been unprecedented before), and extrapolated based on the growth experienced from 1900 to 1970. The conclusion was that if structural changes were not introduced, the world could experience grave difficulties around 2100.

The model examined five interdependent spheres of development, namely industry, resources, pollution, food and population. Changes that affect only one sphere could still cause problems in others, and technological innovations dealing with the expansion of a particular sphere would not affect the general tendency towards a collapse. The report severely attacked the widespread view that the development of technology could improve the environment. Although the report was criticised for its focus solely on the analysis of the Western system as well as the application of the system dynamic method, *Limits to Growth* set the preconditions for a new way of thinking and an awareness of global action programmes and helped to form a new comprehensive view on the global environment.

10.5.3. Third phase: from Stockholm (1972) to Rio de Janeiro (1992)

Two international conferences took place in 1968 and 1972, during which the problems of global environmental protection were discussed; moreover, specific solutions to improve the state were proposed. The first was the Biosphere Conference in Paris, which was in a more scientific vein and in which such problems as the human influence on the biosphere, the effect of air and water pollution, overgrazing of green areas, deforestation and the drainage of wetlands were discussed. The same problems were analysed in more detail during the next meeting – the Biosphere Conference in Stockholm, which attracted international attention to many global problems of nature and the environment.

The United Nations Conference on the Human Environment in Stockholm in 1972 undoubtedly was a turning point and the most important event regarding the establishment and expansion of an international environmental protection movement. It was the first time when environmental problems were discussed and analysed in connection with economic and social development in an international forum. A direct outcome of the conference was the establishment of a new United Nations agency: United Nations Environment Programme (UNEP), which marked the transition from the environmental protection form of 1960 to the establishment of a movement that dealt with the environment protection politically and globally – a much more serious movement of the 1970s, thus confirming the trend towards emphasising a human-inhabited environment affected by humans and underlining the importance of a marked conservation and protection of nature. At the beginning of the 1980s, there were about 13 000 non-governmental organisations in the developed industrial states (30% had been established in the previous decade) and 2230 in the developing countries (60%). The environmental non-governmental organisations in the developing countries provided an alternative to the corrupt governments.

The environmental protection movement was a significant force in the struggle for independence in eastern Europe and the Baltic states – Estonia, Latvia and Lithuania. The rapid expansion of the movement probably was fuelled by the objections to the decisions made in Moscow regarding the development of industry and the use of natural resources; moreover, it was generally confirmed that extensive pollution is a significant factor contributing to the deterioration of human health.

The conference in Stockholm triggered many international initiatives and activities.

Figure 10.13. Opening of the United Nations Conference on the Human Environment in Stockholm, June 5, 1972

The Geneva Protocol on long-range transboundary air pollution (adopted in 1986) proposed quantitative goals. The document in question was reconciled with the European Commission and the North Sea Declaration. It was decided to reduce the amount of pollution caused by heavy metals, toxic and volatile organic substances and biogenic substances by half up to 1995.

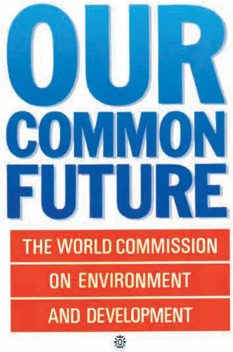
Figure 10.14. Gro Harlem Brundtland, ex-Prime Minister of the Kingdom of Norway and Chair of the World Commission on Environment and Development

The Baltic Sea Declaration signed in Ronneby in 1990 was an important step to ensure the implementation of environmental protection measures agreed upon internationally on a local scale. An action programme was approved coordinated by national and international experts and financial institutions, including the International Bank for Reconstruction and Development, the European Investment Bank, the Nordic Investment Bank and the European Bank for Reconstruction and Development. Programmes and regulations to cut the pollution were adopted on a local scale. In 1992, the plan was backed by the Baltic Sea Environment Declaration, which ensured the possibility to further guarantee the economic strategy of financing environmental actions.

In accordance with the United Nations General Assembly Decision of December 1983, the World Commission on Environment and Development was founded, and the position of chair was entrusted to Gro Harlem Brundtland.

The task of the Commission was to single out critical problems and formulate their solutions planned as a renewed research to ensure the emergence of multilateral solutions and restructure international economic corporation. The commission organised public conventions in all five continents, and the report *Our Common Future* prepared by the Commission was published in 1987. The report was widely used by the United Nations and others in order to emphasise the possibilities of implementing the set goals in each state. The definition of sustainable development was an agreement on political principles, arrived at through a difficult process, which would serve as basis for a careful and responsible monitoring and use of the resources of the Earth.

> *'Sustainable development is development that meets the needs of our generation without compromising the ability of future generations to meet their needs.'*



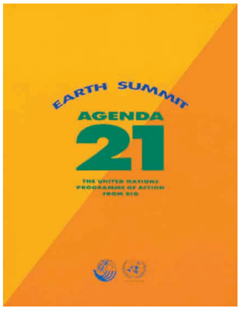


Figure 10.15. United Nations publications are issued in huge editions worldwide

The process of founding Green Parties took off – as early as 1972 in New Zealand, later in 1973 – in Great Britain, 1974 – France, 1978 – Belgium and West Germany, 1979 – Switzerland and Luxembourg, 1980 – Finland, 1981 – Sweden, 1982 – Austria and Ireland, 1983 – the Netherlands and 1984 – Italy. In the elections of the European Parliament in 1984, Green Parties from seven states took part.

The Green Party of Latvia was founded in January 1990 as the first new political party in Latvia before the Declaration of Independence on May 4.

A new ideological turning point in the environmental protection movement was needed in order to be able to formulate the new philosophy of life, like the Club of Rome had done before. In *Gaia: A New Look at Life on Earth* by James Lovelock, published in 1979, the general arguments were accompanied by a new comprehensive view, namely that the humankind is only part of a much greater natural system as the processes that take place on the Earth are influenced by all living organisms that inhabit the planet. They are inseparable, interrelated and form a unity – the biosphere.

10.5.4. Fourth phase: the period of integration

The United Nations Conference on Environment and Development that took place in Rio de Janeiro in June 1992 was the most diverse and large-scale conference ever organised by the United Nations. 179 state representatives and 120 state leaders partook in the Conference. Preparations for the conference took two and a half years, and its progress was widely reported by the press. Many national delegations with representatives of governmental, municipal, business, scientific, non-governmental and other organisations took part in the debate with the institutions of the United Nations. The discussion touched upon issues of international importance – protection of the atmosphere; the use of the oceans, freshwater and land resources; preservation of biological diversity; careful application of biotechnology; and problems regarding toxic and solid waste and hazardous chemical substances. Five documents were signed at the end of the conference, signifying joint national interests and the reached unanimity. This conference was very significant for the future development of the debate on sustainable development, negotiations between developed and developing countries and for the process of explaining the relations between environment and development.

Figure 10.16. United Nations Conference on Environment and Development in Rio de Janeiro, 1992 – the meeting of 103 state leaders

The conference was opened by the United Nations Secretary-General Boutros-Boutros Ghali on June 3, 1992, and Fernando Collor de Mello, President of Brazil, was elected President of the Conference. The Conference adopted the Rio de Janeiro Declaration on Environment and Development, Agenda 21, the Statement of Principles on the Management, Conservation and Sustainable Development of All Types of Forests, the United Nations Framework Convention on Climate Change and the United Nations Framework Convention on Biological Diversity.

At the conference, an important United Nations commission – Commission for Sustainable Development (CSD) – was founded; its goal was to sum up the results of the conference and monitor how the Agenda 21 was implemented on a national, regional and international scale in order to ensure worldwide sustainable development.

Agenda 21 called upon the governments to develop a strategy that would further and ensure sustainable development by attracting non-governmental organisations and the general public. Agenda 21 particularly emphasised the necessity of having multilateral partnership with international organisations, state governments and municipalities, business organisations, non-governmental organisations and different resident groups. The document daringly suggested to develop an environmental development plan for the 21st century. It required that a general inventory in all spheres be performed to assess their sustainability, connecting the spheres and developing action plans for the future. Thus, the guidelines for and structure of implementation of future action were set. The 40 chapters of Agenda 21 (over 500 pages) are classified into four main parts:

- social and economic issues;
- resource conservation and management for development;
- establishing the role of the main action groups;
- determining and solving the most important issues.

However, the main problem of Agenda 21 is the lack of actual financing. Approximate expenses estimated by the secretariat of the Conference amounted to EUR 430 billion a year, 100 billions of which should be covered by international financial aid. These sums seemed unrealistic, taking into account the opportunities of attracting and exploiting financial resources.

A report on implementation of Agenda 21 was submitted at the meeting of the United Nations World Commission of Environment and Development in the summer of 1997. Global Environmental Facility (GEF), established due to the report of the United Nations World Commission of Environment and Development in 1987, planned on spending only EUR 0.93 billion in the period of 1991 to 1994 and EUR 1.33 billion in 1995 to 1998, most of which would be spent on global climate change, international water pollution and protection of biological diversity and the ozone layer. On the whole, international financial aid (including multinational and bilateral financial cooperation) to developing countries has decreased because of political and economic factors. At the end of the Cold War, some of the financial resources due for developing countries were shifted to the former Soviet Block countries. In addition, the former market relations between eastern Europe and the developed countries weakened, leaving some of the former Soviet Bloc countries in a political deadlock and forcing them to search for new partners. The cut in international aid was also related to a financial crisis affecting the developed countries. In order to diminish the consequences of the crisis and stabilise the local situation, the countries drastically cut the resources for international financial aid.

In addition, the environment in the countries of the former Eastern Bloc was a concern, as well as the competition between these countries and the developing countries for the economic aid from the West. The former Eastern Bloc countries had to overcome many problems to be able to embrace sustainable development. In May 3-4, 1996, Prime Ministers of the Council of the Baltic Sea States and EU top officials, including President of the European Commission, met in Visby, Sweden. The setting was one of the most remarkable scenes of regional policy making since the end of the Cold War. In the final declaration of the meeting, the issue of environmental protection was high on agenda, including Agenda 21 for the Baltic Sea Region, as well as co-operation and knowledge transfer. Sweden, as the host of the meeting, set aside a sum of one billion Swedish crowns (about 110 000 EUR) to fund the proposed activities with the help of the newly created Advisory Council for co-operation on the Baltic Sea Region issues. During economic difficulties, it is of utmost importance to ensure that environmental protection is a political priority. That can be achieved only if environmental organisations keep pressing the issues and have the support and involvement of the society. In all eastern Europe countries in which Green Parties were a significant force in the struggle for independence, the priorities have gradually changed. Many representatives of Green Parties elected in the first free elections lost their mandates in the next. At the moment, there is a tendency in society for economic problems to come first regarding political action. Despite that, there is some progress regarding advancement towards the drafting and adoption of national sustainable development strategies. Similarly to developed countries of the West, the advance towards sustainable development takes place on several levels of the society: between politicians and the civil service, between regional and local authorities, between different business organisations and residents.

10.6. Recent tendencies in international cooperation on environmental protection and sustainable development

Figure 10.17. First Conference of the Parties of Aarhus Convention

Conference took place in October 2002 after about four years of preparation since its adoption and signing in Aarhus, Denmark, in June 1998. To commemorate the decade of Aarhus Convention, the Third Conference of the Parties was held in Rīga in June 2008

Multilateral international environmental agreements (conventions) are one of the oldest forms of cooperation in solving problems of the environment and nature. After the United Nations Conference on the Human Environment in 1972, international environmental agreements have become the main instrument of global environmental administration; however, the emphasis is on international diplomacy, not technical understanding. Approximately 140 international agreements have been signed, ratified and come into force since 1920; the number of the documents accompanying them (protocols and amendments) is much greater. Some of the conventions and protocols are of greater significance – on degradation of the ozone layer, biological diversity and climate change.

Although the conventions and protocols differ in both their subjects and goals, there are similarities as well. The conventions are international laws that independent countries or institutions have agreed upon. Since the conventions set down the obligations and rights of the countries in a particular sphere, the representatives of the states spend quite a lot of time on harmonising the documents before adoption of the conventions. After that, technical experts develop the project of the convention and submit it to the member states for evaluation. The highest ranking officials of the states sign the convention during an international conference dedicated to the debate on the questions related to the convention. The procedure of ratification takes place after signing; it involves an official decision by the parliament confirming that the convention complies with the national legislation and that the state is willing to observe the rules of the convention and undertake international liabilities. If an established number of states (the minimum number of states needed for the convention to function efficiently is decided by the member states themselves) have ratified the convention, they convene the first conference of the parties of the convention to agree upon the actions needed to implement the convention, including the establishment of the secretariat of the convention, financing, usage of financial means, the procedure of reporting the progress and, if necessary, the criteria for evaluating the conformity of member states. In some cases, expert committees and work groups are formed in order to solve current issues.

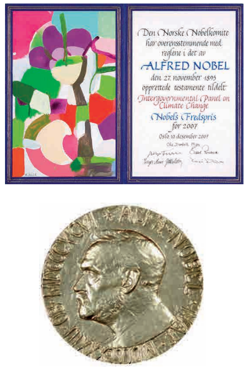


Figure 10.18. Nobel Peace Prize 2007 was awarded to the Intergovernmental Panel on Climate Change

Figure 10.19. The Club of Rome General Assembly

From the right: Queen Beatrix of the Netherlands, J. Cohen, Mayor of Amsterdam, R. Lagos, former President of Chile, R. Lubbers, former Prime Minister of the Netherlands, M. Gorbachev, former President of the USSR, who all took part in the work of the Club of Rome General Assembly in October of 2009

Regarding the making of global environmental policy and development of conventions and their protocols, the role of scientists and experts is invaluable. A good example is the Intergovernmental Panel on Climate Change (IPPC), which consists of approximately three thousand scientists. The results of their research and a mutual exchange and collective interpretation of the results have raised global awareness of the current environmental problems and helped in developing a unified policy for subduing the negative consequences of climate change. The contribution of IPPC has been awarded with the Nobel Peace Prize in 2007.

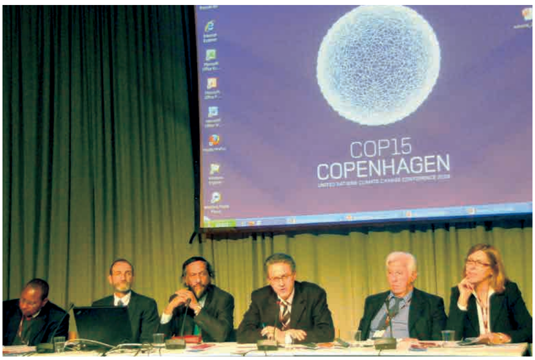


Figure 10.20. Chair of Intergovernmental Panel on Climate Change R. Pachauri addresses the delegates of COP15 in the official opening of Copenhagen Conference on December 7, 2009

Table 10.2. **International conventions on nature and environmental protection**

Conventions and agreements	*Place of adoption*	*Year of adoption*
International Convention for the Regulation of Whaling		1946
Radiation Protection Convention		1960
Vienna Convention on Civil Liability for Nuclear Damage	Vienna	1963
Nuclear Non-Proliferation Treaty		1968
Convention on Wetlands of International Importance, Especially as Waterfowl Habitat	Ramsar	1971
UNESCO World Heritage Convention		1972
CITES Convention on International Trade in Wild Species of Fauna and Flora	Washington	1973
International Convention for the Prevention of Pollution from Ships	London	1973
Convention on the Conservation of European Wildlife and Natural Habitats	Bern	1979
Convention on the Conservation of Migratory Species of Wild Animals	Bonn	1979
Convention on Long-range Transboundary Air Pollution	Geneva	1979
United Nations Convention on the Law on Seas		1982
Convention for the Protection of the Ozone Layer	Vienna	1985
Montreal Protocol	Montreal	1987
Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency	Vienna	1986
Convention on Early Notification of a Nuclear Accident	Vienna	1986
Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal	Basel	1989
Convention on Environmental Impact Assessment in a Transboundary Context	Espoo	1991
Agreement on the Conservation of Bats in Europe	London	1991
United Nations Framework Convention on Biological Diversity	Rio de Janeiro	1992
Cartagena Protocol on Biosafety	Cartagena	2002
United Nations Framework Convention on Climate Change	Rio de Janeiro	1992
Kyoto Protocol	Kyoto	1997
Convention on the Protection of the Marine Environment of the Baltic Sea Area	Helsinki	1992
Convention on the Protection and Use of Trans-Boundary Watercourses and International Lakes	Helsinki	1992
Convention on the Transboundary Effects of Industrial Accidents	Helsinki	1992
Convention to combat desertification in countries seriously affected by drought and/or desertification, particularly in Africa	Paris	1994
Convention on Nuclear Safety	Vienna	1994
The Agreement on the Conservation of African-Eurasian Migratory Waterbirds		1995
Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management	Vienna	1997
Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade	Rotterdam	1998
Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters	Aarhus	1998
Stockholm Convention on Persistent Organic Pollutants	Stockholm	2001

Since as early as the 1960s, scientists have been attempting to link global climate change with anthropogenic action. At the beginning the initiative came from the scientists working on research on the atmosphere, who were trying to make the connection between the impact of the collective action of humankind on the whole atmosphere and its possible changes. This kind of interdisciplinary approach was used in a scientific programme 'Human and Biosphere' carried out by the United Nations Educational, Scientific and Cultural Organisation (UNESCO) from 1971 to 1984. In a way, it set the foundation for interaction between environmental science and environmental politics and enabled solving current global problems more efficiently.

In September 2000, the General Assembly of the United Nations, which 191 member states took part in, signed the United Nations Millennium Declaration and set eight Millennium Development Goals to be fulfilled until 2015.

Figure 10.21. Emblem of the United Nations and the stand at the UN Headquarters in New York with the Millennium Development Goals

United Nations Millennium Development Goals

Goal 1: Eradicate extreme poverty and hunger.
Goal 2: Achieve universal primary education.
Goal 3: Promote gender equality and empower women.
Goal 4: Reduce child mortality.
Goal 5: Improve maternal health.
Goal 6: Combat HIV/AIDS, malaria and other diseases.
Goal 7: Ensure environmental sustainability.
Goal 8: Develop a global partnership for development.

Figure 10.22. Environmental protection activists protest against the world leaders' inability to make decisions on definite and immediate actions to diminish the negative consequences of climate change. Copenhagen, COP15 Conference, December 2009

References

Barrow C. J. (1999) Environmental Management. Principles and Practice. London, New York: Routledge.

Clapp J., Dauvergne P. (2005) Paths to a Green World. Cambridge, Massachusetts, London: MIT Press, 322 p.

Duchin F., Lange G.-M. (1994) The Future of the Environment. New York, Oxford: Oxford University Press. 224 p.

Garrett H. (1968) The Tragedy of the Commons. Science, 162, 1243-1248.

Lomborg B. (2003) The Skeptical Environmentalist. Cambridge University Press. 515 p.

Lovelock J. (2007) The Revenge of Gaia. Penguin Books. 222 p.

Meadows D., Randers J., Meadows D. (2004) Limits to Growth – the 30-year Update. London: Earthscan. 338 p.

Norgaard R. B. (1994) Development Betrayed. New York: Routledge.

Our Common Future. (1987) The World Commission on Environment and Development. Oxford, New York: Oxford University Press. 400 p.

O'Neil K. (2009) The Environment and International Relations. Cambridge University Press.

O'Riordan T. (ed.) (2000) Environmental Science for Environmental Management. Prentice Hall. 520 p.

Orr D. W. (1992) Ecological Literacy. Education and the Transition to a Postmodern World. State Univ. of New York Press.

Revesz R. L., Sands P., Stewart R. B. (2008) Environmental Law, the Economy and Sustainable Development. Cambridge University Press. 437 p.

Ryden L. (ed.) (1987) Sustainable Baltic Region. Vol. 1-10. Uppsala: Uppsala University, Baltic University Programme.

Ryden L., Migula P., Andersson M. (eds) (2003) Environmental Science. Uppsala: Baltic University Press. 824 p.

Sachs J. D. (2009) Common Wealth: Economics for a Crowded Planet. Penguin Books. 386 p.

State of the World – 2009. (2009) Worldwatch Institute. London: Earthscan. 260 p.

Taylor G. (2008) Evolution's Edge. New Society Publishers. 306 p.

Thiele L. P. (1999) Environmentalism for a New Millenium. New York, Oxford: Oxford University Press. 302 p.

Weizsacker E. von, Lovins A. B., Hunter Lovins L. (1997) Factor Four: Doubling Wealth, Halving Resource Use. London: Earthscan. 322 p.

Directorate-General for the Environment of the European Commission. Accessible: *ec.europa.eu/environment/index_en.htm.*

European Commission. Accessible: *ec.europa.eu/index_en.htm.*

European Environment Agency. Accessible: *www.eea.europa.eu.*

Intergovernmental Panel on Climate Change – IPPC. Accessible: *www.ipcc.ch.*

United Nations Department of Economic and Social Affairs. Accessible: *www.un.org/esa/desa.*

United Nations Development Programme Homepage. Accessible: *www.undp.org.*

United Nations Environment Programme. Accessible: *www.unep.org.*

Uppsala University Baltic University Programme Homepage. Accessible: *www.balticuniv.uu.se.*

11. ENVIRONMENTAL MANAGEMENT: LEGISLATION, POLICIES, INSTITUTIONS

11.1. Legislation of environmental protection

The terms 'environmental law' and 'environmental legislation' are used for denoting the measures of environmental legal protection.

Environmental law means a body of legislative provisions, regulating the public rules of conduct in the area of environmental protection. Environmental law is a relatively new and complex area of public law, which includes such legal provisions of constitutional law, administrative law, criminal law and administrative procedure law that aim to ensure and promote environmental protection. Environmental law belongs to public law, which means that, to protect the environment, the state prescribes for the public certain requirements that must be followed. If a person fails to comply with these requirements, the state may use coercive measures against such a person, imposing a corresponding penalty or ordering to eliminate the adverse effects on the environment resulting from the violation.

What are the rules of conduct contained in legal provisions can be ascertained through studying the sources of law. Environmental law consists of several types of legal sources, representing the written law (legislation) and the unwritten law (general legal principles and customary law). In addition, the sources of environmental law can be divided into the basic sources (laws) and ancillary sources (case law or the rights of judges and jurisprudence – legal science or jurists' law).

The main source of environmental law is the law (external legal provisions), *viz.* the written sources of law, which include generally binding rules of conduct. The generally binding legal provisions comprise laws adopted by parliament, regulations issued by government and binding rules issued by local authorities. Furthermore, EU legislation – including regulations, directives and decisions – is binding to the European Union Member States. EU environmental legislation is developed mainly in the form of directives that the Member States must then integrate into their national law.

National environmental legal protection is also based on international legislation. For the most part, they are international agreements (conventions, protocols) to which the Member State is a party.

Therefore, environmental legal protection is associated with both environmental and natural resource protection and sustainable use, and the protection of human health from harmful environmental factors in the following environment-related areas:

- water protection,
- soil protection,
- protection against noise in the environment,
- ambient air protection,
- nature and biodiversity conservation,
- waste management,
- turnover of chemical substances and products, including biocides and pesticides,
- turnover of genetically modified organisms,
- various emissions and releases into the environment,
- environmental impact assessment,
- access to environmental information and public participation in environmental decision-making at the state level,
- urban and rural spatial planning.

The term 'environmental legislation' is associated with national environmental law, and it mostly refers to legal acts (laws of parliament, regulations of government and local authorities) that pertain to the environment or help to achieve the national aims of environmental policy – to preserve, protect and improve environmental quality, provide for sustainable use of natural resources and ensure a high-quality living environment.

For the purpose of the law, 'the environment' is taken to mean an aggregate of natural, anthropogenic and societal factors. Obviously, 'the environment' includes not only natural factors (the natural environment) but also human beings and their impact on the natural environment.

11.1.1. Law as an environmental protection instrument

Various cultures of the world have different understandings of law. The conception of law largely depends on what is recognised as the sources of law. The world's developed countries, including European countries, have quite similar conceptions of law. The laws of these countries belong to the so-called Western law, where 'law' usually means a body of legislative sources regulating community life. The laws of the Baltic Sea region countries belong to the continental European law family or civil law system. Although this system may also include unwritten law, the main recognised sources of law are written – above all, the laws adopted by national parliaments. Generally binding rules of conduct or regulations, to a limited extent, may also be issued by executive powers – the government and local authorities. The legal provisions of the highest legal force – the State Basic Law (Constitution) – are at the top of this hierarchy.

In many countries, environmental protection is a constitutional norm. For example, Article 115 of the Constitution of the Republic of Latvia stipulates: 'The State shall protect the right of everyone to live in a benevolent environment by providing information on environmental conditions and by promoting the preservation and improvement of the environment.' Several state obligations can be derived from this constitutional provision – to protect the right of everyone to live in a benevolent environment, to provide for the preservation of such environment and to promote the improvement of the environment as well as to ensure public access to environmental information.

The countries that belong to the continental European civil law system have codified laws, which are often referred to as codes. In several countries, there are civil and criminal as well as environmental law codifications. For example, Germany, France and Sweden have environmental codes. Latvian environmental regulatory standards are included not just in one but in several laws: the Environmental Protection Law, the Law on Pollution, the Law on the Conservation of Species and Biotopes, the Law on Specially Protected Nature Territories, the Protection Zone Law, the Waste Management Law.

Figure 11.1. German Parliament (Reichstag) building in Berlin

The dedication *Dem Deutschen Volke*, meaning 'For the German people', can be seen on the architrave.

The laws of such countries as the United Kingdom and United States, in turn, belong to another group of Western law – the English-Saxon common law system. In this group of laws, the basic recognised sources of law are both the laws adopted by the parliament (legislative statutes) and judicial precedents. Therefore, in these countries, the so-called rights of judges have significantly greater weight than in continental Europe.

Human behaviour is governed by different types of rules – from etiquette and morality to legal provisions. However, only the latter are contained in the sources of law and are binding.

Environmental laws are primarily focused on solving environmental problems and include measures that should be taken in order to prevent known environmental problems. Compliance with the requirements of legal provisions makes possible to eliminate environmental damage or to reduce its impact.

To prevent human-created environmental problems successfully, we need to develop a strategy to change human behaviour, making it more environment-friendly. Since law is the most effective regulator of social behaviour, it is widely applied in order to change social behaviour patterns in the use of the environment. In general, environmental law is primarily incentive and disincentive rules of conduct contained in environmental legislation. They underpin different areas of life. Hence, the law may set a binding framework, within which economic, technical, informative, educational and other measures are often implemented on their merits.

The desired behaviour can be achieved with two kinds of methods, working as a 'pie' or a 'whip'. The 'pie' strategy means that the law stimulates the implementation of environment-friendly behaviour in a way that compliance with environmental protection requirements is beneficial. The 'whip' strategy, in contrast, provides for measures impeding specific actions. These measures have to be such that the disadvantageous consequences of environmentally unfriendly actions would inhibit people from these actions. The 'whip' strategy is most commonly used in the provisions that impose penalties or other coercive measures for non-compliance with environmental protection requirements.

Usually, environmental law drafts are developed by executive powers or politicians, adopted by the legislator and implemented by specialised state or municipal environmental protection authorities, whereas courts exercise control over the compliance with these laws. Unlike it is with other social norms, the compliance with legal provisions can be enforced by compulsion. Therefore, only the law has a specific implementation process – the legal provision.

Legal provision is a mechanism for ensuring the compliance with legal provisions or their fulfilment. In order to make this process work, the state has created relevant institutions (authorities) – courts, police, prosecutor's office, specialised state environmental departments – which have been granted a monopoly of coercion. The coercion mechanism grants the state (the law enforcement bodies) the lawful right to apply coercive measures against the violators or non-observers of the law. The coercive measures themselves are established by the law, and they are quite different.

The state has the right to monitor the compliance with environmental legislation. Such control can be exercised by state environmental inspectors. If non-conformities with the requirements of environmental legislation are found during inspections, state environmental inspectors may, for example, issue binding injunctions (administrative acts) for temporary suspension of the company's operations, draw up statements of the cases for less grievous (administrative) violations and impose statutory administrative penalties for these violations. Although the law also provides for criminal liability for environmental legislation offences, in practice the environmental regulatory violations are classified primarily as less serious violations. The most common punishment for environmental violation is an administrative fine, whose amount is usually fixed by the law.

If it is economically more profitable for a company to pay fines and compensate for environmental damage instead of continual conformity with environmental protections requirements, such a situation is indicative of the inefficiency of the legislator's chosen 'whip' strategy, as it does not promote the compliance with these requirements.

11.1.2. Law and environmental science

Environmental science and environmental law each has its own specific tasks. Environmental science explains and forms understanding about the processes taking place in the natural environment, interaction going on among the elements of nature and between humans and the natural environment. By contrast, the task of the law is to regulate social relations for the purpose of protecting and improving the environment and to solve the related disputes. Although the environmental science and law are quite different areas, they are at the same time closely related. Regulation of social relations in such a way that human activity would not have any destructive environmental impact is possible only if both the legislature and general public have an understanding of the processes in the environment and their causes, as well as of the impact of various human activities on the environment. If the knowledge of environmental science was not taken into account in drafting environmental legal provisions, it would be impossible to achieve the goals of environmental law. Consequently, such a normative regulation would have to be regarded as an ineffective means of environmental protection. Environmental science, in turn, without binding environmental protection regulations, would not have the tool for transforming the behaviour of society and directing it into a more environment-friendly direction.

11.1.3. Law and environmental ethics

Regulating social relations, the law as such is silent on ethical issues. Is it acceptable to degrade the natural environment and to consume a large part of the planet's natural resources during one generation? What kinds of actions in relation to nature should be regarded as good or bad? What is the moral value of nature? Answers to these questions should be sought in environmental ethics. Environmental law is based on two main conceptions of environmental ethics – anthropocentrism and ecocentrism. According to the anthropocentric approach, the environment should be protected in the interests of human welfare – today's environmental protection conserves environmental resources for future consumption. The ecocentric approach, in turn, implies that the environment (nature) has an intrinsic value in itself; therefore, the human responsibility is to protect it without regard to the benefits humans could obtain from it, and to provide for the possibility to exist not only for humans but also for other living beings. Contemporary environmental law is primarily anthropocentric.

In the legal system, animals or nature in general are usually regarded as legal objects, which can be equated to things. Usually, neither nature nor animals are recognised as legal entities which may have rights. Only humans possess rights. Hence, the law, being for the most part anthropocentric, guarantees the priority and protection of rights and interests just to one species – humans.

11.2. Legal principles of environmental protection

Environmental protection principles are guiding ideas, on the basis of which the state develops its environmental policy. Compared with legal provisions as sufficiently clear rules of conduct, the environmental protection principles are more abstract. Therefore, they are often considered as an intermediate stage between environmental policy and environmental law. These principles are established by law and serve primarily as guidelines for the Development of environmental laws and regulations.

There are several environmental protection principles effective in the European legal space – the principle of high level of environmental protection, the precautionary principle, the principle of preventive action, the assessment principle and the 'polluter pays' principle.

When new environmental laws and regulations are adopted, **the principle of high level of environmental protection** prohibits deteriorating the existing level of environmental protection.

The precautionary principle does not allow to start on an environment-affecting action until the information has been obtained as to how high a risk exists and what measures have to be taken to reduce it. If the research process reveals a threat, the precautionary principle calls for precautionary measures, despite the fact that there is some uncertainty as to whether the risk is indeed real. The aim of the precautionary principle is not to permit certain actions only when the risk to the environment or human health is equated to zero, but to assess the magnitude of the risk and, in case of need, take the necessary measures.

Although all kinds of chemical substances we use on a daily basis help to simplify our life, they can imperceptibly harm us in the future. Humans have created thousands of new chemicals, and only part of them have been proven dangerous and, therefore, are prohibited to use (for example, the use of some plastic softeners in children's toys). At the same time, there is a great deal of chemicals still in use whose hazards have not yet been properly researched. These substances are contained in various goods and products that are widely used on a daily basis, and we can take them in with food, breathe in with air or absorb through the skin. Until now, before a country could be prohibited to produce some chemical substance, its hazardousness had to be conclusively proved. Now the European Union law has brought new binding requirements based on the precautionary principle – over 30 thousand existing and new chemical substances will have to be tested with regard to their effect on human health. It is no longer the country but manufacturers and importers of chemical substances who must obtain certain information on the properties of these substances and test them to determine their impact on the environment and humans, as well as guarantee their safe use, that is, prove that the substance is not hazardous.

The principle of preventive action requires to prevent pollution or other harmful impacts on the environment or human health as much as possible, or, if it is unfeasible, then at least to prevent further spreading of these harmful effects and their negative consequences. The principle of prevention combines two EU environmental protection principles – the principle of preventive action and the principle of causation.

The principle of preventive action is implemented through such regulatory enactments which require, for example, compliance with the environmental pollutant emission standards or waste management regulations. Waste should be processed and disposed of as close to its place of origination as possible (the proximity principle), and each state or local government should, as far as practicable, by itself treat and manage in an environmentally sound manner the waste generated at its territory (the self-sufficiency principle).

The assessment principle prescribes: if the consequences of an action or project can significantly affect the environment or human health, they must be assessed before such an action or project is permitted (commenced). If it becomes evident after the assessment that the action or project in question will adversely affect the environment or human health, the government may allow it on condition that the expected positive result for society as a whole will exceed the harm that the respective action or project will have caused to the environment and society.

The assessment principle clearly attests to the aforementioned anthropocentrism of environmental law. Moreover, 'the expected positive result for society as a whole' may be related to the implementation of economic interests, such as the construction of roads, dams, pipelines, nuclear power plants. Therefore, the environmental legislative regulation is aimed not so much at prohibiting any negative impact on the environment than at controlling and minimising this impact as far as reasonably practicable.

'The polluter pays' principle requires that the costs of assessment, prevention and mitigation of pollution as well as the costs of elimination of its effects are borne by the person whose activity has caused the pollution in question.

There are over 3000 sites (including land areas and waters) identified in Latvia that are actually or potentially contaminated with hazardous substances. On the European Union scale, there are over 300 000 such sites. But this should not happen at all.

The earlier environmental regulatory framework has not prevented the possibility of origination for such sites, because the environmental polluters could have easy ways to avoid responsibility. Now, there are new legislative acts passed on the basis of 'the polluter pays' principle in order to make the polluters accountable for restoring the contaminated sites to their previous environmental condition.

Persons – individuals or companies – whose actions have caused harm to the environment, i.e., such detectable changes in the environment that are likely to have significant negative impacts on both human health and also the environment (e.g., waters, specially protected areas, species, habitats) are required to restore the previous state of the environment, covering the pollution removal and environment restoration costs.

'The polluter pays' principle will fully come into effect when each contaminated site is decontaminated and the decontamination costs are covered by the persons who have caused the respective pollution.

To put 'the polluter pays' principle into effect, it is important to determine who is the polluter and for what the polluter must pay.

Companies engaged in such economic activities that have a high environmental risk – for example, carrying dangerous cargos, transporting chemical (oil) products via pipelines, operating fuel filling stations or producing cement, glass fibre or chemical products – have to prevent the damage caused to the environment due to their activities and to restore the environment to its previous state even if these companies have not violated environmental regulations. In legal context, this is called strict liability.

Latvia and other former Eastern Bloc countries have established the register of historically contaminated (and potentially contaminated) sites. The new legal acts on environmental liability are not applicable to the restoration of these sites, as their requirements are not effective with regard to past events. Therefore, specific requirements have been set for the restoration of such sites. First of all, the responsibility lies with the person whose activity has caused the pollution. If that person cannot be held liable due to objective reasons, then the current landowner will have this responsibility. The contaminated site has to be restored to such an extent as to prevent the contamination from spreading or entering the groundwater, so that it would no longer be hazardous for human health or the environment.

'The polluter pays' principle is not applicable in cases when it is impossible to determine who has caused the environmental pollution, or the company at fault for the pollution is known but no longer exists, while the contaminated site has not been transferred to another owner. In the Baltic states, for example, these sites are mainly the territories formerly occupied by the Soviet army as well as the sites contaminated by the former Soviet plants.

If the actual polluter does not exist anymore, and the contaminated site does not have another owner, the clean-up of the contaminated site has to be covered from the state budget. Besides, legislation usually establishes less stringent requirements for the state – the polluted site restoration works are to be carried out only if the state has sufficient funds for this purpose. This is one of the reasons why past pollution continues to be a major environmental problem in the Baltic states.

Finally, in the cases provided by the law, 'the polluter pays' principle is also extended to the manufacturers of specific products.

Figure 11.2. Deepwater Horizon offshore drilling rig on fire, Gulf of Mexico, 2010

Vessels combat the fire on Deepwater Horizon while the United States Coast Guard searches for missing crew

The Deepwater Horizon oil spill (also referred to as the British Petroleum (BP) oil spill) was a massive oil spill in the Gulf of Mexico that was the largest offshore spill in the history of the United States and among the largest oil spills in history. The spill stemmed from a sea-floor oil gusher that resulted from the 20 April 2010 Deepwater Horizon drilling rig explosion. The explosion killed 11 platform workers and injured 17 others. On 15 July, the leak was largely stopped by capping the gushing oil wellhead.

The quasi-official Flow Rate Technical Group estimated the oil well was leaking 5600 to 9500 cubic metres of crude oil per day. This volume is approximately equal to the 1989 Exxon Valdez oil spill every four to seven days. The resulting oil slick covered at least 6500 km^2, fluctuating daily depending on weather conditions. Scientists have also reported immense underwater plumes of dissolved oil not visible at the surface.

The spill caused extensive damage to marine and wildlife habitats as well as the Gulf's fishing and tourism industries. Crews worked to protect hundreds of miles of beaches, wetlands and estuaries along the northern Gulf coast, using skimmer ships, floating containment booms, anchored barriers and sand-filled barricades along shorelines. The USA Government has named BP as the responsible party, and officials have committed to holding the company accountable for all cleanup costs and other damage.

11.3. Process of enforcement of environmental legislation

11.3.1. Approaches to elaboration of legal documents

Environmental quality is affected by different factors – pollution, excessive deforestation, land cultivation and unreasonable fertilisation, the use of substances or organisms foreign to the natural environment. To encompass all these and other factors, several approaches and measures are used in the legal regulation of environmental protection.

First, environmental law contains regulations that focus on quantifiable and stationary sources of pollution. These are mainly standards for the companies that operate different stationary industrial (technological) equipment. Since the operation of such equipment leaves a more or less extensive environmental impact, they are called polluting activities. State exercises control over the polluting activities: they are permitted only if the company previously obtained a relevant permit from a competent national environmental authority. Moreover, the law requires the competent national environmental authority to issue such a permit on condition that the emissions of pollutants into the environment would be maximally reduced.

Second, environmental law includes mandatory regulations, which require the state to take complex steps to achieve certain objectives defined by law. For example, EU legislation requires from the new Member States that water in their natural and artificial water bodies must be in *good condition* by 2015. The water condition is defined as good if it does not endanger the survival of diverse aquatic ecosystems even if the effects of human activities can be detected. This kind of regulation is also referred to as the ecosystem approach. The objectives in other environmental areas are set forth in a similar way: to mitigate climate change and reduce greenhouse gas emissions as well as to facilitate the removal and recycling of waste (for example, packaging waste recovery standards).

Third, there are also regulations for various state and local government decision-making processes. For example, to decide on where to locate a waste disposal landfill, a special procedure has to be carried out – *the environmental impact assessment* for this landfill. During this process, the potential impact is assessed and actions for the reduction of this impact are planned, and alternative landfill sites are ascertained. A decision on locating the landfill at a particular site can be taken only after the environmental impact assessment. Such regulation is necessary in order to ensure that every decision, whose implementation may affect the environment, would be taken on the basis of sufficient information regarding its possible impact on the environment, to take into account environmental considerations in addition to the economic and social ones, to make such decision-making transparent and to facilitate the interested public to become involved in the decision-making process and influence it, in particular the residents in the vicinity of the planned object who may be directly affected by the project in question.

All three approaches are used in the normative regulation of environmental protection. However, going back to the beginnings of environmental laws, it is possible to trace their changes and Development s over time. Initially, environmental legislation was focused on controlling the pollution from industrial enterprises. Then it became clear that other economic activities also degrade the environment – agricultural and forestry practices, uncontrolled use of chemical substances and products, construction works at environmentally sensitive areas, such as the sea coast and river banks and lake shores. Therefore, the legislature began to set forth the objectives to be attained within specified periods of time and to require complex measures – gathering and analysis of information on the actual situation of the environment, planning and execution of measures required for the attainment of objectives set. Moreover, such a planning process should be transparent, involving the community as well.

11.3.2. Environmental legislation instruments

Binding regulatory requirements are also called standards. Often they are regarded as the core of environmental law, because they, as the means of 'command and control', directly set forth certain requirements (standards) for environment-polluting activities, substances and products, as well as for the implementation and application of environmental regulations. There are several categories of standards: emission standards for the permissible pollution that can be released from the end-of-pipe of industrial facilities into the environment; the environmental quality standards for such environmental components as air, surface and ground water and soil; standards for different processes, requiring the use or abandonment of specific technologies, materials or practices. For example, there are requirements to use the 'best available technologies' in cellulose production, or specific fishing gear and dragnets with specific mesh sizes in fishery. Likewise, specific environmental standards are established for the production, use and disposal of various products; for example, the environmental requirements for fuel, laundry detergents and electronic appliances.

Voluntarily made commitments (self-regulation). Self-regulation is rooted in the idea that enterprises voluntarily assume additional commitment for environmental protection.

Another form of self-regulation is *environmental audit*, which is carried out within the framework of the *environmental management and audit system* established by law. When a company becomes involved in this system on a voluntary basis, it commits itself to develop and implement its own environmental policy and regularly conduct environmental audits, that is, to check whether the company's environmental policy is being implemented, whether the environmental protection investments are not spent in vain and whether the company's business activity meets the environmental protection requirements. The purpose of such a system is to encourage the involved companies to be more environment-friendly, at the same time gaining some benefits from the involvement in the system – to raise their competitiveness in the market.

Another self-regulation measure is *eco-labelling*. Eco-labels provide consumers with information on the environmental impact of products.

In Europe, a transition to a new public management model took place in the 90s of the 20th century. In accordance with this model, public management takes over the management style typical to the private sector, i.e. it is aimed at economy and efficiency. As a consequence, environmental regulation has been increasingly using economic means with the objective to promote economy that would be economically viable and environmental friendly at the same time.

Examples of such means include environmental taxes (in Latvia – the natural resource tax) and the EU's newly implemented pollution rights trading system. This system provides that a company which, as a result of technical improvements, has not used all the allocated CO_2 and other greenhouse gas emission allowances, can sell the unused allowances to another company.

To make the right decisions, accurate information is needed first of all. The information at the basis of making political decisions and dealing with environmental issues has to be public and transparent. Today, obtaining environmental information has become one of the state functions. Environmental laws require the state to establish and maintain registers and databases, providing access, for example, to the data on environmental situation, pollution and its sources, state-issued permits for polluting activities, environmental monitoring, environmental impact studies, as well as environmental legislation and policy documents.

At the same time, public access to the environmental information at the disposal of the state has been significantly liberalised – in the EU Member States, the right of public access to this information is stipulated by law. The state has to create publicly available and free online databases, the publicly available environmental information has to be presented in an easily perceivable and comprehensible manner, the requesters of the environmental information do not need to provide reasons why they need this information. The receipt of environmental information can be restricted only in the cases specified by law. However, it should be noted that these requirements for public access to environmental information does not apply to private companies.

Finally, the right of society – any of its member – to apply to court, so that it would verify whether the decisions or actions of the state itself (its authorities) comply with the requirements of environmental legislation can also be considered a means of environmental legal regulation.

11.3.3. Dialogue with society and the role of society in environmental protection

The authority of public opinion is crucial in environmental protection. Environmental laws can have the necessary support and effect only if the majority of society understands the importance of favourable environment for human life and the need to preserve the environment. Public pressure often expedites the drafting and adoption of laws.

Besides, there are such legal provisions today, whose implementation is not even possible without public activities. A vivid

To facilitate this objective, the Aarhus Convention guarantees the public (any of its member) the following individual rights:

- the right to access environmental information at the disposal of the state;
- the right to participate in environmental decision-making;
- the right to apply to court in environmental matters.

example is the Aarhus Convention on public rights in environmental matters. This Convention deals with environmental protection in close relation with human rights. The Convention is particularly significant, as it not so much prescribes mutual obligations for the participating countries than determines the basic principles how to form relations between the state and the public in the area of environmental protection, establishing an internationally recognised standard.

The Aarhus Convention envisages environmental protection as a precondition for ensuring the public welfare and right to live in an environment that is not hazardous to health.

The Aarhus Convention is based on the idea that if the public is active and well-informed, it can be a powerful force in sustainable and environment-friendly Development. Therefore, the members of society are not required to provide reasons as to why they need any specific environmental information.

Figure 11.3. In need of strong environmental legislation

Turkish environmentalists in anti-nuclear/anti-dam protest in Istanbul, on the 24th anniversary of the Chernobyl disaster.

The public has a right to participate in adopting environment-related decisions. These can be decisions on issuing permits for polluting activities or construction of major infrastructure objects. The public has a right to participate in the environmental impact assessment process of proposed projects and in the preparation of various environment-related planning documents – including spatial planning – establishing restrictions for the use of land and buildings (constructions).

Exercising their rights to participation, members of the public may express their opinions and concerns with regard to the proposed plans, projects or activities. The institution that takes the decision, in turn, has an obligation to take into account and evaluate these opinions and concerns. Furthermore, if the institution rejected the people's protest against the proposed project, it is obliged to give reasons for such rejection. If these public rights are violated, everyone, including non-governmental organisations (environmental associations), is entitled to apply to court to protect the infringed public rights.

Nowadays, the role of the public in state governance has increased significantly in both environmental policy drafting and implementation. For all that, it is up to the members of the public themselves whether they exercise these extensive rights.

11.4. Environmental policy

The aim of environmental policy is to identify and resolve environmental problems, establish a system of environmental legislation and set tasks to ensure environmental quality. Environmental policy should promote the participation of the public in solving environmental issues and ensure the integration of environmental protection and nature conservation issues in all economic sectors.

Environmental policy provides a framework for the environment and natural resource use, so that an adequate economic structure and social security could be established for the needs of society. Environmental policy has more general and broader functions than environmental management. The latter provides for the practical implementation of the former. The purpose of environmental management, in turn, is to ensure that national economy utilises the natural resources efficiently, that the necessary goods are manufactured and the necessary services – received, and that pollution is reduced to the level which is not harmful to human health and ecosystems. In a word, environmental policy can be considered as environmental protection and conservation strategies.

Environmental policy provides a framework for setting objectives and tasks for environmental protection and for ensuring the improvement of environmental quality. Environmental policy consists of several interrelated stages that form a cycle.

At an early stage of policy-making, usually an understanding emerges that there is an environmental problem. Then the problem to be solved is defined more exactly through collecting and analysing the known facts, data and information. After that, the environmental policy planning documents are being developed – concepts, guidelines, strategies, programmes and plans, subsequently to be approved by the parliament or government.

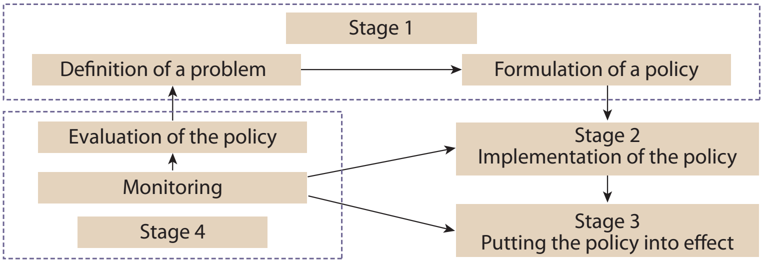


Figure 11.4. Stages of environmental policy-making

Medium-term policy planning documents usually reflect the current situation, formulate environmental policy objectives, challenges and directions for action to attain these objectives. In many cases, the overarching objective of environmental policy is to build a framework for the preservation and restoration of environmental quality as well as for sustainable use of natural resources, at the same time limiting the impact of adverse environmental factors on human health.

Some of the key problems to be solved are:

- air quality standards in major cities are frequently exceeded, and transport emissions make the largest proportion of air pollution;
- eutrophication of inland waters is increasing, and it is largely caused by agricultural activity; this factor, in turn, adversely affects water quality in the Baltic Sea;
- in the situation of economic crisis, the use of recycled materials cause a problem; considering the substantial drop in prices and demand, the attainment of waste recycling targets are also becoming problematic;
- planning documents for economic sectors do not sufficiently reflect various environmental factors – air quality and noise in traffic planning documents, geological and flood risks, industrial accident prevention measures;
- society's lack of understanding about the dependence of long-term availability of natural resources on the forms and methods of current economic activities;
- lack of long-term, systematic scientific studies on the potential impacts of climate change on the environment in many of the EU Member States, climate change risks, effects of climate impact mitigation measures on economy, as well as lack of economic and social adaptation measures and programmes prepared for their implementation;

- lack of funding to control the compliance with the statutory requirements.

Solving of environmental problems directly depends on the level of society's knowledge on environmental protection. Environmental education and communication are the main tools of raising public awareness. Communication is an ongoing two-way exchange of information between decision-makers and the general public. It is an important policy tool, having a major role throughout the implementation process of the policy and environmental management. Although communication has a different function at each policy and management Development and implementation stage, these stages are interrelated.

The most important communication functions are:

- to make information available to the public;
- to draw public attention to specific issues or problems;
- to involve the public in discussing and solving specific problems;
- to provide information on new Development s in various fields, promote the exchange of ideas and knowledge;
- to facilitate changes in public behaviour and attitudes.

Environmental education is one of the most important means of raising public environmental awareness in the progress towards a sustainable society. The role of environmental education is:

- to promote community Development in a way that would harmonise the spiritual and material needs and interests;
- to increase substantially the public sense of responsibility, involving citizens and society in environmental conservation and rehabilitation;
- to educate the public about the environment and nature, raising the level of knowledge and self-education opportunities;
- to involve the responsible organisations, educational institutions, experts and enthusiasts in the process of environmental education, thus supporting the national and local initiatives.

Environmental education helps build environmental awareness – to study the environment, identify its problems and obtain a careful and conscientious attitude towards it. Environmental education of staff involved in environmental management and protection should be considered a prerequisite for the environmental protection system to exist. Environmental education justifies the need for mobilising financial resources for environmental policy challenges. Environmental education, decision-making and practical activities are based on research and knowledge of environmental science. Environmental education and environmental science are a foundation for setting environmental policy and social sustainability goals and dealing with problems.

Environmental education is needed in order to make possible drafting and implementation of laws and regulations – not only those on environmental protection but also on economic sectors, addressing internationally significant environmental protection problems at the local level, studying the environmental quality and developing new environmental technologies, and ensuring protection of the environment in general.

At schools, environmental education and education for sustainable Development are generally integrated into various subjects according to their specific content, ensuring the continuity and coordination in various stages of education.

Research Development and the use of knowledge and environmentally sound technologies is the principal economic Development path that can ensure sustained prosperity. Consequently, it is essential to develop exact principles for the content and objectives of environmental education and science. Environmental studies should focus not only on knowledge acquisition and research proficiency but also on the skills to identify and address environmental protection problems significant for society.

11.5. Environmental management system – from vision to implementation

Environmental protection is a set of measures of environmental quality preservation and sustainable use of natural resources, whereas its purpose is to eliminate, mitigate or prevent environmental damage. Environmental management system is a continuously repeated cycle of planning, implementation, outcome evaluation and more precise definition and improvement of further action. It is used in state and local government as well as in commerce – in order to identify and implement environmental quality improvement goals.

This approach helps to ensure continuous improvements and achievements. The set of measures includes:

- planning of the overall process, starting with the environmental situation assessment for the purpose of setting goals;
- actions required for pilot projects ran for the purpose of gaining experience and knowledge and becoming prepared for the main tasks;
- control of the process and situation changes, including monitoring to make adjustments if necessary;
- implementation of the process to achieve the set objectives, evaluating performance at regular intervals to determine whether the achievements match the plans.

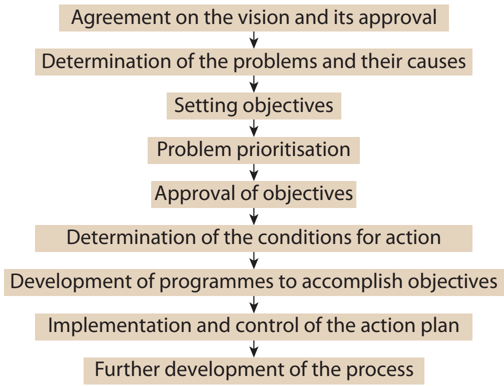


Figure 11.5. Scheme of the Development of a general environmental protection system

11.5.1. Discussion and approval of the environmental policy vision

To initiate an integrated environmental assessment and the necessary management process, first of all there must be such a desire. It can be expressed by state and local government leaders, deputies, non-governmental organisations, citizens groups, environmental protection enthusiasts or business representatives. Regardless of what caused the initial impetus, leaders must be ready to listen and to prepare adequate documentation for starting the process to resolve issues relating to financial resources and administrative involvement. Since most government institutions, municipalities and other organisations have already been integrated into the processes associated with the use of the environment for rendering services or the environmental impact assessment, the deputies must be ready to listen to their voters' wishes and put them into practice.

After the initial steps of the process, an increased interest should be awaked on national or community levels. Also, the necessity of various activities or campaigns should be carefully studied by interviewing people. However, it is quite difficult to evaluate the need for comprehensive long-term planning. Various communication methods can be used, giving priority to those which have already been successful in cooperation with public groups. Interest groups may already exist, but in many cases they come into being when there is an increase in public interest about environmental issues.

The next task is to prepare a statement of reasons for the entire action. It should include public participation principles and vision of the future that could be acceptable to a wide range of representatives of public groups and even those who have different opinions.

To initiate such a process, it is useful to review society's environmental values and to draw the participants' attention to the environmental preservation and protection needs. Objects of value can be visited, such as individual natural features, wildlife systems, historical buildings. Besides, the spirit of unity and patriotism within the community, territory-specific crafts and decorative art activities and the ability of mutual understanding should also not be neglected. Ideas can be generated at meetings of various groups, using the brainstorming method. The ideas put forward should be kept for the vision Development stage.

Vision could include population health, keeping in mind that the associated problem area is usually much broader, involving, for example, such factors as deterioration of the demographic situation or a higher mortality rate of lung disease in a district and on average in the country. One of the causes of problems in the human environment is deterioration of the living standards; consequently, the task of normalising the situation can be related to the improvement of economic situation.

It should be taken into account that the vision cannot be borrowed from the neighbours or someone else – it can only be single and specific to a particular country or community. The vision should express the society's future expectations and aspirations that can be articulated through such important factors as health, living standard, lifestyle, environmental quality and future directions of economic Development. The vision should be brief, composed in an easily comprehensible language, and it should reflect the main directions toward which the society will have to work hard.

11.5.2. Determination of environmental problems and their causes

Environmental information has a major role in environmental policy Development and environmental management system operation. This information comprises knowledge and data obtained through environmental studies, statistical information, long-term and systematic observations of the environment, society and its activities. Environmental information consists of the observational data, whose gathering, processing, analysis and interpretation make the facts describing the processes in the environment and society. Environmental information should enlighten the scientists, politicians and persons working in environmental management, so that they would be able to make the correct policy decisions – i.e. matching the actual situation and the environmental challenges in the region – and to make well-founded and rational environmental protection and management measures. An important task of environmental information is to identify environmental problems before starting the processes that may threaten the environment quality. The efficiency of environmental policy and management is dependent on the completeness and quality of environmental information.

In the context of good management provision, it is important that citizens have access to the Internet, enabling them to follow the activities of the state government, local government and non-governmental organisations and business processes as well as to engage in discussions and decision-making process by sending their opinions and recommendations to relevant authorities in an electronic form.

Environmental information cannot be restricted access information – it should be public. The public is entitled to have environmental information on

- environmental situation, including information on water, air, soil and subsoil, flora, fauna, natural areas and landscapes, biodiversity, species and habitats and their interactions, as well as information on genetically modified organisms;
- anthropogenic pressures and activities that affect or may affect the environment;
- environmental protection measures affecting the environment;
- reviews and reports on environmental protection, policy planning documents in the field of the environment, laws and activities affecting the environment, cost-benefit analysis, economic analysis reports in relation to the implementation of environmental policy.

EMEP (European Monitoring and Evaluation Programme) is a scientifically-based policy-driven programme under the Convention on Long-range Transboundary Air Pollution for international co-operation to solve transboundary air pollution problems.

If a decision on a vision is taken, it is necessary to clarify the specific environmental problems. There are several methods that can be used for collecting and processing information in order to ascertain the real problem and its scope. The collection of data on certain parameters to assess the root of an environmental problem is of particular importance. The process should move on in such a way that the degree of its complexity would be acceptable to the public – from a highly sophisticated computer programme to a brainstorming session on local environmental issues that people know well enough.

Even a small summary of data may give a hint regarding the current situation in a district, across the country, the EU Member States or the world at large. Such information can also be obtained from the European Environment Agency, the statistical bureaus and municipal authorities of the EU Member States.

The data shown in Figure 11.6 predict a reduction in this metric of approximately 2 $\mu g/m^3$ or more per year in central and north-western Europe. Smaller reductions are predicted outside this region (Spain, Balkan countries, the Baltic and the Nordic countries).

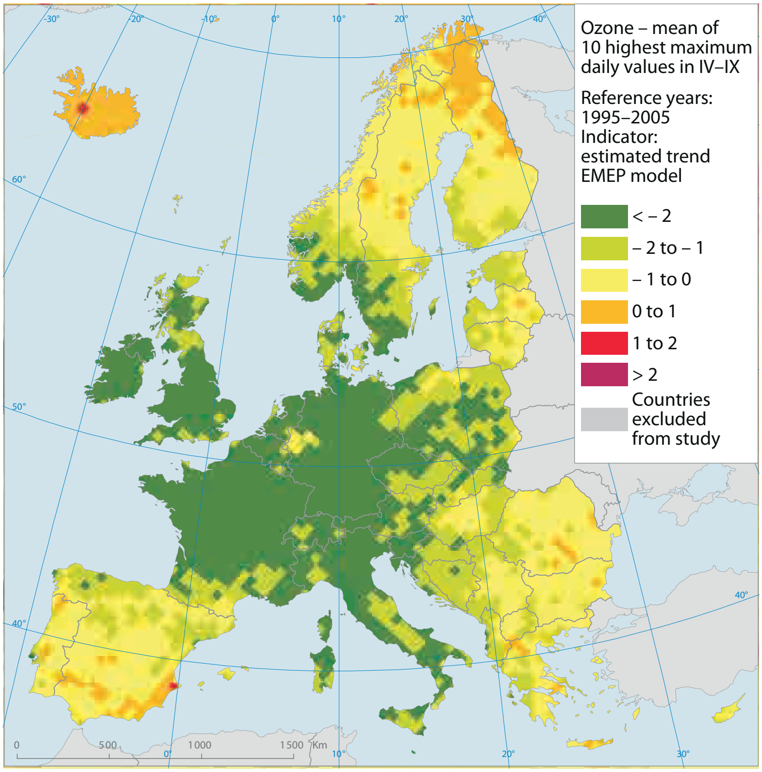


Figure 11.6. Ozone estimated trend in MTDM calculated using the EMEP model

Note: MTDM – the mean of the ten highest daily maximum ozone concentrations (based on hourly mean data) during April-September, corresponding approximately to the mean of the data ≥ 95 percentile.

It is very difficult to carry out in practice a complete, objective analysis, covering all environmental problems, without delimiting the research scope. Any observer is more or less subjective, and any perception is influenced by the manner in which an observation or measurement is made. Nevertheless, a relative objectivity can be achieved.

Some method of objective analysis could apply to a particular component of the environment, such as water, or to a specific pollutant. In the case of subjective analysis, the opinions of the society and citizens as to what they perceive as environmental problems are ascertained. Although this type of information does not give a complete picture, because the respondents usually do not mention problems that cannot be seen or felt, it may give some direction where to look for the environmental damage. One example is the noise. The perception of noise as a problem can be very different. The noise that is loud according to physical measurements, might not be a problem if people need it. Even so, if the noise is strong and damages hearing, it is a problem.

People should be interrogated as to what kinds of environmental problems they see and how, in their opinion, these problems should be ordered by importance. Such information can be obtained from population surveys, by listening to the views of elected deputies and by other methods.

Estimations regarding future problems should also be made. Some of these problems can affect the entire country, such as a sharp increase in packaging material waste due to increased import of goods, or growing road traffic intensity due to increasing number of cars.

When problems have been identified, an accurate and possibly complete database should be created. It should be based on a suitable choice of parameters, which can vary in each specific case of local environmental problems. These parameters can be both subjective and objective, but, in any case, they must be measurable. Otherwise, it will be impossible to determine whether any changes have occurred in the environment – environmental quality improvement or degradation.

Sometimes the choice of standards can lead to sharp political debates. Even if the administration prepares research reports and, based on these results, proposes parameters or standards for selection, ultimately it is government or municipal council that has to take the final decision.

The EU has established a common framework of reference for standards. Still, in some cases, standards are also set at a national level, and local governments retain the right to use more stringent requirements, but not vice versa, i.e. they are not entitled to lower the national standard requirements.

Furthermore, when the indicators or parameters have been chosen and the corresponding measurements have been performed, they need to be assessed in order to understand the environmental situation. If the parameters have corresponding standards, it is possible to make comparisons and assess whether a given parameter exceeds or does not exceed the standard.

If a problem is detected, it is necessary to study its causes and consequences. In many cases, it is obvious that there are a number of phenomena which point to existing problems, while in other cases it is not so clearly perceivable.

Each problem can have a hierarchical chain of causes, and, in case of its successful detection, there is a possibility to detect the root causes and deal with them first. If changes are found in the natural environment of a rural area, for example, some populations of species become larger, while some – disappear, the cause could be changes in agricultural activity, which could have been focused on more intensive production. This effect, in turn, could have been caused by some farm's decline in income, forcing them to decide on a sharp increase in production to at least avoid impairing their quality of life. However, the deeper the root cause could be sought in the national food price policy and regulations on food product import.

Figure 11.7. Music shop window in Stockholm (Sweden)

Environmental and social problems (e.g., noise pollution) can be used to advertise the business.

If the root causes are discovered, some problems can be easily resolved. The situation may be improved – even if slightly – in any case. If enough data have been gathered and assessed, a public information material should be prepared – a report on environmental situation or a similar document.

At any rate, the process should be pushed on, so that, by combining the administrative management of the environmental impact assessment with the initiation of practical measures, it would be possible to improve environmental quality. It may later become the basis for creating an environmental monitoring system.

11.5.3. Setting environmental policy objectives

Environmental policy objectives reflect society's expectations about the future. They may be scientific, social, cultural, long-term or short-term. They do not always need to be measured or evaluated quantitatively or against some previously accepted standards or criteria. Even more important, the objective should include environmental philosophy, which should underpin the vision even if its Development has been entrusted to the experts of specific fields. Environmental philosophy should also appear in environmental action plans – as a mediating ground between the vision and specific objectives.

Once the objectives have been formulated, one can see that immediate completion of all the objectives is not possible due to budgetary and other constraints. However, it is very important to identify all the necessary works and to have a general view on the entire course of action, before taking a step back and starting to set priorities. Setting priorities is likely to be the most difficult of all parts of the process, so it should be done with full awareness of the potential benefits.

Problems can be sorted in order of importance by several criteria:

- how much the pollution levels exceed the standards;
- how big the costs of environmental damage elimination will be;
- what the expected expenses for health care or other important areas are.

The analysis of the collected information should reveal the areas which have the greatest weight, which significantly influence the process in general, or which require immediate action to prevent irreparable harm. There are many known methods to set priorities, and it is better to choose several of these methods because they give an opportunity to consider the process from different perspectives.

One of the most widespread methods is comparative risk analysis of population health, environmental protection and quality of living conditions. Problems are ranked taking into account the selected criteria and mutual agreement on the acceptable level of risk.

Environmental impact assessment is carried out in order to decide on what the consequences will be if nothing is done to change the existing situation and on what will be achieved through specific measures. Both of these borderline cases are very important – if they show that an action of a relatively small impact can be carried out relatively easily with few resources, it could be taken on to achieve rapid success, which would also earn public recognition and decrease the likelihood of unforeseen side results. Conversely, if a serious problem cannot be solved or the situation cannot even be improved by using all the available and potential resources, then it is better to divert resources to other targets.

All possible choices need to be analysed for their impact on the environment, costs and social implications. Impact on the environment involves two groups of issues: assessment of the effectiveness of a choice if the objective is achieved and the potential unforeseen impact on the environment. Even if it is not possible to predict the consequences of each action, it is desirable to determine many of them. Although each situation is unique in a sense, much can be learned from others, using their experience.

11.5.4. Types of action to accomplish environmental policy objectives

If priorities are clear, types of action should be determined with the purpose of accomplishing the objectives stated. The types of action can be carried out as special projects, which also stipulate some policy compliance and maintenance. Economic methods and the use of the mass media can also be suitable and may have a positive effect on the behaviour and attitudes of officials and citizens. For the purpose of implementing a common strategy, influence on the behaviour of certain social groups should sometimes be exerted. For example, it is necessary to guarantee that the land use would not be detrimental to nature protection objectives. The land owner, obtaining a permit from the environmental authority for performing a desirable activity, at the same time commits himself or herself to participate in an environmental protection measure. In this way, private land owners or users can also contribute towards the accomplishment of the objectives set.

Administration staff do not necessarily have to be green-minded, but their attitude may have serious effects on solving the environmental problems. For example, the municipal employee who is in charge of procurement for local needs can greatly affect the state of the environment if he or she truly understands the situation.

This applies to both state administration or local government leaders and the officials lower in the hierarchy, who may come up with good ideas – for example, to hold regular discussions with local residents and hear their views. So, this is an opportunity to engage in the environmental protection process and timely prevent problems that might arise, for instance, due to a mistake in the environmental action plan or because of dissatisfaction of the population.

Social implications of all the proposals should always be taken into consideration. Shut-down of a company caused by its failure to comply with environmental requirements would have significant consequences, such as job loss. In such a case, it would be difficult to take a political decision on the suspension of operations of the company, and, most likely, such a decision would not be taken after all. A better solution would be to start cooperation with the company's management in order to make improvements and move towards the compliance with environmental requirements gradually.

Moreover, jobs are not the only social problem. Requiring people to change their daily patterns, habits or traditions is always quite difficult. Besides, such factors as the cultural level and religious beliefs need to be taken into account. At the global level, the extent of these kinds of difficulties can be seen, for example, in the debates associated with birth control.

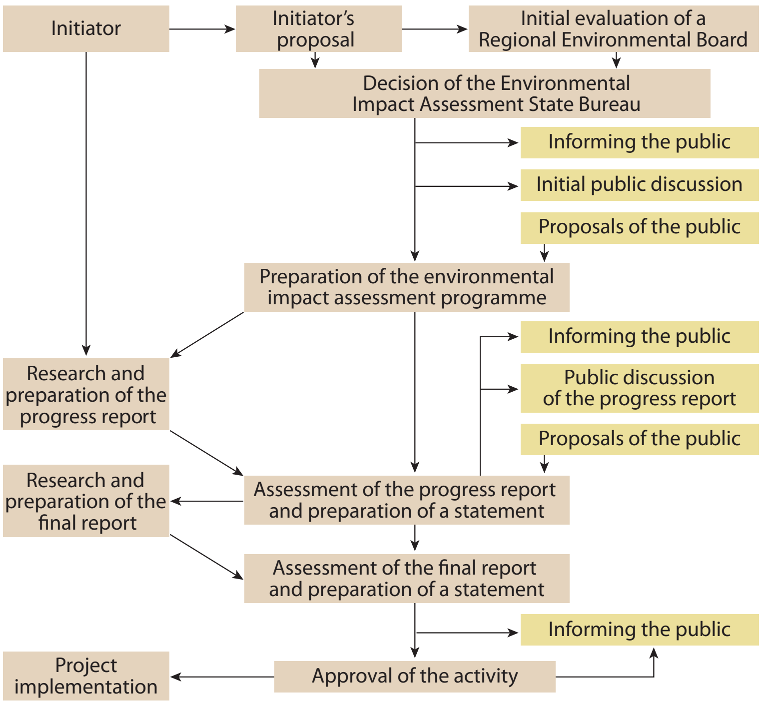


Figure 11.8. Procedure for environmental impact assessment

Changes that may be disadvantageous to population's standards of living or family budget will always be perceived as unacceptable – as long as people's thinking is changed by way of education or information.

11.5.5. Development of the programmes to accomplish environmental policy objectives

The Development of an environmental programme is initiated on the basis of the analysis performed and objectives set. The programme may contain separate plans or projects and a variety of methods to ensure information exchange, legislative compliance and economic conformity. Projects can be carried out by the institutions or organisations that have won the state or local government tenders.

Accomplishing a certain objective, the agricultural pollution discharge into streams, rivers and lakes can be reduced in rural areas. Another objective could be related to the diversification of regional economic by attracting tourists. A clean river with nature trails and opportunities to observe wildlife could draw the attention of tourists; at the same time, a certain balance should be kept in order to avoid the rise of new conflicts between tourists and nature.

For example, if the river is used for water sports Development, it can adversely affect the fauna of the river. Additional difficulties and new challenges may arise, and they have to be dealt with to avoid contradictions in the overall execution of the environmental programme.

As of 1 May 2004, when several Baltic Sea region countries became Member States of the EU, the environmental impact assessment of planning documents was begun, which is actually a strategic environmental impact assessment under the EU Directive 'Assessment of the effects of plans and programmes on the environment'. The objective is to assess the possible environmental impacts of the implementation of planning documents and to involve the public in discussions and decision-making regarding these documents, as well as to develop proposals to eliminate or minimise the negative impacts. The strategic assessment is carried out during the planning document preparation, before it is submitted for approval.

The strategic impact assessment should be performed for those planning documents, whose implementation can significantly affect human health and the environment, including the planning documents in the areas of agriculture, forestry, fisheries, energy, industry, transport, waste management, water management, telecommunications, tourism and mining, as well as the planning documents related to regional Development, land use, spatial planning and the use of EU co-financing.

The strategic environmental impact assessment procedure ensures that the developers of various planning documents (Development plans and strategies for national economy and its various sectors as well as spatial Development plans) are responsible for assessing how the implementation of these documents would affect the environment and for introducing the draft documents and environmental reports contained there to the public, so that the latter could express opinions.

11.5.6. Implementation and control of the environmental action programme or plan

The implementation of an environmental action plan begins with the determination of institutions and persons who will be responsible for the execution of the programme or its parts. For some programmes, there is no need to appoint the responsible leader. In this case, collective decisions are taken by people who are directly involved in the process.

To ensure a successful implementation of programmes, different organisational models can be used. These models can have a more or less complex or simple hierarchical structure. However, in all cases it is necessary that the persons in charge have sufficient environmental knowledge and understanding of the nature of the process as a whole. In some cases, short-term training or seminars on individual substantive issues relating to the programme implementation may be held.

The implementation of a programme requires resources. If funding for the attainment of the programme objectives has been approved and allocated and the responsible persons – designated, the implementation of the programme or plan can be started. Careful planning of the implementation process is crucial for a successful completion of the programme.

Process control is a very important element in implementing programmes because it ensures two important things, namely, it guarantees that the expected environmental improvement effect will be achieved and dangerous side effects will not arise.

The opportunities of using environmental indicators towards the attainment of specific objectives should be evaluated in order to ascertain the progress made. If a programme is implemented for reducing nitrogen dioxide concentrations in urban air for a specific amount (the yearly threshold for human health safety set by the law is 40 $\mu g/m^3$), the assessment of the environmental status change can be made by determining the NO_2 concentration and comparing it with the concentration at the time of beginning the programme.

It is difficult to carry out systematic and regular measurements of a parameter that is difficult to control. Yet, such controls are required. If environmental monitoring data show that the programme does not bring the desired results, it should be reassessed to determine the changes needed.

If the programme implementation process has been appropriate, but the desired result has still not been achieved, the reasons of failure have to be looked for. They could be, for example, incorrect assessment of the cause of the problem; however, in most cases, the reason is inaccuracies in the calculation.

Then there are three options:

- to stop this activity completely and look for an activity of different type;
- re-assess the same process and then go on with it;
- persistently continue the process already begun, at the same time looking for some alternative action.

Table 11.1. **NO_x emissions and projections: current and projected progress towards the ceiling**

	Denmark	*Latvia*
2010 emission ceiling	127 Gg	61 Gg
2010 WM projections (existing measures in place)	126.0 Gg	45.1 Gg
Distance to NO_x emission ceiling in 2007	39.7 Gg	–18.2 Gg
Comparison of 2010 emission ceiling with WM projections 2010	–1.0 Gg	–15.9 Gg

Depending on the scale of the required changes, additions can be included in an already existing programme, or the programme can be modified. Even if it is possible to fit the changes in the existing programme, this fact should be made known to the public.

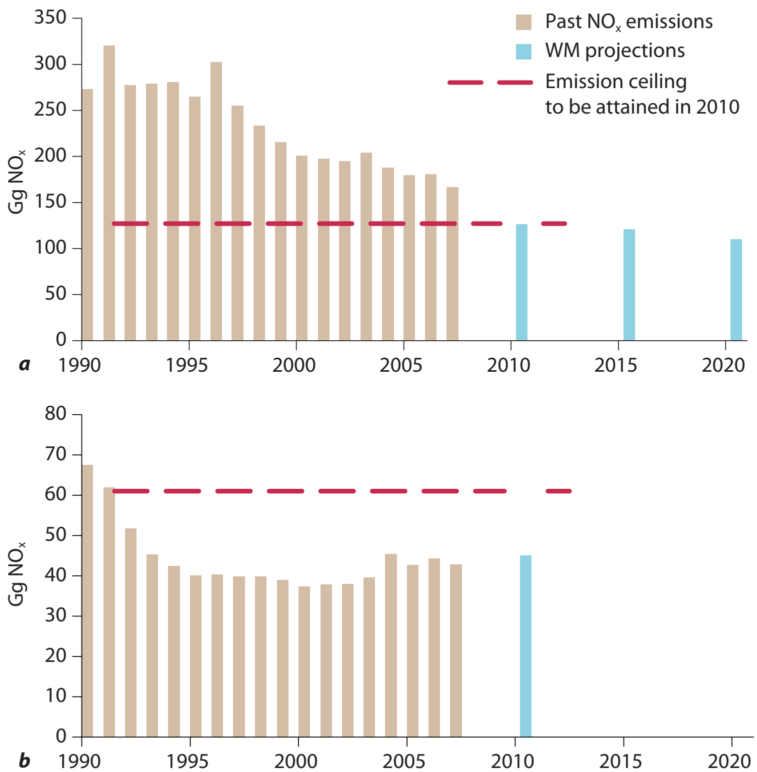


Figure 11.9. NO_x emissions and projections in Denmark (***a***) and Latvia (***b***)

Reporting by the Member States under Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on national emission ceilings for certain atmospheric pollutants.

Environmental monitoring

Environmental monitoring comprises systematic observations, measurements and calculations of environmental situation, pollution, emissions, population and species needed for the environmental assessment and planning of nature conservation and measures for controlling the effectiveness of environmental protection. In environmental information system Development and implementation, resource accounting data are of great importance – cadastral data, information on the country's socio-economic situation and Development tendencies provided by the national statistical data analysis and public opinion polling. Effective decision-making in environmental protection is possible only if all the available information is analysed.

Sometimes the environmental monitoring information – which is an essential part of the environmental information system – is stored in various institutions, in the databases of different size and accessibility or only on paper. This factor makes it difficult for the interested persons – the public, decision-makers, experts – to obtain and use this information for environmental problem-solving or decision-making. Unfortunately, it is often impossible to know whether the monitoring data are being aggregated and made available.

Environmental monitoring is divided into the environmental situation, environmental policy implementation and early warning monitoring.

The environmental situation monitoring consists of systematic observations carried out in different natural environments in order to detect and assess changes caused by natural processes or anthropogenic impacts. This includes the monitoring of emission, spreading and concentration of pollutants and assessment of the status of ecosystems, including the Development of proposals for ecosystem quality improvement. The monitoring of environmental situation is carried out regularly in order to obtain information on environmental conditions and changes, and also, in specific cases, to assess the environmental condition changes after an accident or after the implementation of an environmental protection programme or to obtain information on the environmental impact of a particular object.

The policy implementation monitoring is a systematic assessment of environmental changes effected through the implementation of environmental policy measures. This is one of the key elements in the Development of environmental policy and assessment of its effectiveness as it helps to ascertain the causes which impede the attainment of environmental quality targets in conformity with the environmental quality regulations and standards.

The main functions of the early warning monitoring is early detection of dangerous changes in environmental quality, fast-track provision of information and making of short-term forecasts.

The execution of an environmental monitoring programme is coordinated by the state institution of appropriate level. This institution is also responsible for public access to the information on pollutants and monitoring results on the Internet. In addition, it prepares and provides the required information for the European Environment Agency and the European Commission.

Each part of the programme provides information on such aspects as monitoring objectives, legislation stipulating the need for monitoring, criteria for environmental quality assessment, indicators, priorities and funding necessary for the execution of the programme.

The implementation of the programme helps to avoid duplication in the environmental monitoring work, when several institutions perform similar functions for limited state budget funds. The environmental monitoring programme also ensures monitoring in the areas which are important at both national and EU levels. These programmes primarily consist of the following components:

- air monitoring,
- water monitoring,
- soil and land surface overgrow monitoring,
- biodiversity monitoring,
- radioactive contamination monitoring,
- climate change monitoring.

Figure 11.10.
Environmental sampling to monitor tasks

Furthermore, each part of the programme consists of monitoring subprogrammes. Each subprogramme contains such data as the monitoring network description, inspection schedule, parameters to be determined, actual and potential methods to be used, Development tasks, necessary maintenance costs and investments. The executor of the specific monitoring programme part creates and maintains one's own monitoring data processing system in accordance with the legislative requirements for national information systems.

Environmental monitoring information is structured according to the principle of causality, grouping the data in a logical five-phase model: driving force – load – condition – impact – action.

The indicators are integrated into a single causal chain, showing:
- what causes the problem;
- why it occurs;
- what are its effects;
- how and by what means the problem can be solved.

Environmental policy and environmental quality indicators

In the 1970s, reports in different fields were started to be prepared according to the principle of causality, logically grouping the characteristic variables into the causal model, later on extended into the five-phase model by the Organisation for Economic Co-operation and Development (OECD). The characteristic variables contained in the analytical model are called indicators.

Certain methodological requirements are set for the indicators, so that countries and specialists could come to an understanding when they are published and interpreted in various reports. The indicators must be credible, represent certain time periods and regions, scientifically accurate, obtained through standardised methodologies, expressed in standardised units, verifiable, easily perceptible and comprehensible, comparable, non-duplicating, necessary to users, sensitively reacting to changes, predictive of processes and ensuring acquisition of information at a reasonable cost.

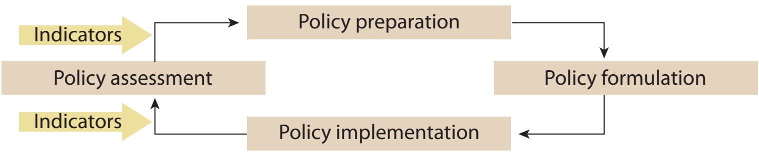


Figure 11.11. Policy cycle and indicators

The main function of indicators is to provide information during the decision-making process and to adjust different levels of policy according to the policy cycle scheme.

The use of sustainable Development indicators in such a scheme is focused on the interaction links between the traditional indicators, but the synergistic effects in such a complex system are stronger as the direct cause-effect interactions.

Integrating economic, environmental and social issues, the following factors are taken into account:

- sectoral and sectoral strategic plans and programmes, indicating how environmental issues are integrated into these plans and programmes;
- whether appropriate action plans with specific time and resource planning have been developed;
- what environmental policy measures and methods are used in the particular sector;
- what general-purpose policy measures function particularly widely and effectively;
- what the major projects of environmental protection or conducive to environmental protection are.

Table 11.2. EU Sustainable Development Strategy implementation progress for the period between 2000 and 2009

SDI theme	*Headline indicator*	*EU-27 evaluation of change*
Socio-economic development	Growth of GDP per capita	☀
Climate change and energy	Greenhouse gas emissions*	☁
	Consumption of renewables	☁
Sustainable transport	Energy consumption of transport relative to GDP	⛅
Sustainable consumption and production	Resource productivity	☀
Natural resources	Abundance of common birds**	⛅
	Conservation of fish stocks***	⛈
Public health	Healthy life years****	⛅
Social inclusion	Risk of poverty****	⛅
Demographic changes	Employment rate of older workers	⛅
Global partnership	Official development assistance*****	⛈
Good governance	[No headline indicator]	:

* EU-15 ** Based on 19 Member States *** In North East Atlantic
**** EU-25, from 2005 ***** From 2005

☀	Clearly favourable change/on target path
⛅	No or moderately favourable change/close to target path
☁	Moderately unfavourable change/far from target path
⛈	Clearly unfavourable change/moving away from target path
:	Contextual indicator or insufficient data

Granting environmental issues a dominant or equal status compared to economic and social issues, the system is supplemented by sectoral indicators, creating mutual integration (at the policy level – the integration of environmental issues in sectoral policies; at the indicator level – eco-efficiency and energy intensity estimates, analysis of environmental profiles).

Under the EU Sustainable Development Strategy, EUROSTAT uses approximately 100 indicators, while the headline indicators characterise the key directions of sustainable Development (socio-economic Development, sustainable consumption and production, social inclusion, demographic changes, public health, climate change and energy, sustainable transport, natural resources, global partnership, good governance).

11.5.7. Further development of the process

For a better assessment of the progress made, and to ensure the communication of the results to the public, a few questions have to be answered in the first place: have all plans been fully implemented? Have the planned results been achieved?

General environmental quality indicators should be used in order to ascertain whether the measures taken have led to the expected environmental situation improvement. For example, if the city's thermal power plant is modified to replace peat fuel with natural gas, the expected result in reducing nitrogen dioxide emissions from the power plant to the planned level can be fully achieved. Nevertheless, the overall air quality improvement effect can be relatively low as the atmospheric concentration of NO_2 remains about the same as in previous years. Apparently, not enough attention has been paid to another source of NO_2 – transport, which in many cases is the main source of NO_2 pollution in cities.

The reasons for not fully achieving the planned results have to be analysed. Environmental monitoring data will also show which objectives of the programme have been achieved and in which cases adjustments are necessary in order to make progress towards what has not been achieved yet. Admittedly, it could be quite an unpleasant situation, because nobody wants to assume responsibility for mistakes. However, it is essential to know the real reasons, not just carry out formal investigation. Emphasis should be put on shared learning from mistakes, so that the implementation of measures would get better in the next stage, given the actual capabilities of employees and budget allocation.

The programme implementation results should be communicated to the public through the mass media, creating conditions for the public to express comments and discussions. Only in this way people can get the true information on the process that has taken place and its outcomes. It could also be the basis for future discussions on the adjustments necessary to the environmental measures.

In essence, the whole process can be likened to a continuous spiral, not to a closed circle, for each successive loop is a little more advanced than the previous one and strives toward the ultimate goal – a sustainable society. Even if the ultimate goal is not reached in the near future, society will still seek to mitigate the impact on the environment both locally and globally.

11.6. Voluntary measures of environmental policy

Any form of business or production as well as any individual action can have an impact on the environment, causing environmental degradation. At the same time, the public interest in environmental issues and the impact of specific manufacturing processes or companies on the environment is increasing. In addition, the lawmakers are also interested to make the operations of companies, plants, industrial units comply with the requirements of the law, whereas consumers want them to operate or provide services in an environment-friendly way. Finally, employees also want to work in a safe and healthy work environment.

An environmental management system helps satisfy the interests of everyone by establishing certain requirements or principles related to processes and products, by preparation of information, as well as by granting companies and plants certification of an independent authority (certification organisation) that they meet certain requirements.

In this way, not only those concerned can feel safe and have assurance but also every company is enabled to make its business comply with the environmental requirements, as it has an opportunity:

- to identify and assess the company's impact on the environment,
- to formulate the company's intentions in the area of environmental protection (the company's environmental policy and environmental protection objectives),
- taking into account the financial and technical capabilities, to develop the company's environmental programme aimed at systematic and targeted reduction of the negative impacts,
- to know the legal requirements regulating the company's business activity,
- to perform accountancy of the company's resources and analysis of the environmental pollution caused.

Figure 11.12. Emblem of the International Organisation for Standardisation

The International Organisation for Standardisation (ISO) is a worldwide federation of national standardisation organisations, which brings together approximately 100 countries. ISO is a public organisation established in 1947.

The ISO 14001 standard developed by the International Organisation for Standardisation is a global-scale environmental standard.

The EU Eco-Management and Audit Scheme (EMAS) was developed and implemented as a management tool to promote environmental protection, wise use of resources and improvement of public information activities at the companies and organisations that voluntarily participate in the system.

In the EU Member States, this system works since 1995, initially involving industrial enterprises. As of 2001 – after the adoption of the European Commission Regulation (EC) 761/2001 allowing voluntary participation by organisations in a Community eco-management and audit scheme (EMAS) – the system is open to all organisations. Upon completing the necessary preparation, any enterprise, company, institution and municipality can participate in this system. The companies and organisations which are included in the EMAS register obtain the right to use the EMAS logo.

In 2009, the Commission decided to extend this environmental management system to all its activities and buildings in Brussels and Luxembourg as described in Decision C (2009) 6873. The European Commission recognises the positive contribution it can make to sustainable Development as a long-term goal through its policy and legislative processes as well as in its day-to-day operations and decisions.

To be more specific, the Commission commits to minimise the environmental impact of its everyday work and continuously improve its environmental performance by:

- taking measures to prevent pollution and to achieve more efficient use of natural resources (mainly energy, water and paper);
- taking measures to reduce overall CO_2 emissions (mainly from buildings and transport);
- encouraging waste prevention, maximising waste recycling and reusing and optimising waste disposal;
- integrating environmental criteria into public procurement procedures and into the rules regarding the organisation of events;
- complying with relevant environmental legislation and regulations;
- stimulating the sustainable behaviour of all staff and subcontractors through training, information and awareness raising actions;

- progressively extending all the above to all its activities and buildings;
- systematically assessing the potential economic, social and environmental impacts of major new policy and legislative initiatives and promoting the systematic integration of environmental objectives into Community policies;
- ensuring the effectiveness of environmental legislation and funding in creating environmental benefits;
- promoting transparent internal and external communication and dialogue with all interested parties.

Organisations are registered with the competent national authority that assesses the applicant's compliance with the requirements of the Regulation, registers organisations and decides on their removal from the register temporarily or permanently.

Pursuant to the requirements of the Regulation, a participating organisation should, involving and educating all its employees, identify environmental problems, develop an environmental policy, establish and implement an environmental management system and internal auditing system and draw up an environmental statement, which includes information on what has been accomplished and what is planned for the future. The environmental management and audit system of the organisation is inspected by an independent, accredited environmental assessor (verifier), who also approves the environmental statement. The information included in the environmental statement is updated on a regular basis and is freely available to the public and all interested persons.

With the emergence of 'green' marketing, 'green' consumer organisations began to develop as well. Consumer protection authorities have been active already since the 1960s. Marking of goods to indicate that they are environment-friendly has been promoted in many countries, including USA, Canada, Germany and Sweden. In most cases, independent agencies measure certain products against similar products to determine which of the compared products cause less environmental impact. Germany was among the first countries introducing the 'green' labelling of goods (1978).

In the EU eco-label system, ecological criteria are developed for each group of goods or services. These criteria are aimed at reducing the product environmental impacts throughout their life cycle – from manufacture to disposal. The criteria are developed by expert working groups under the guidance of the presiding Member State, in consultation with the representatives of all interested parties (manufacturing and retail businesses, state and public consumer protection and environmental protection organisations).

This was one of the ways to influence consumer behaviour, helping them to identify the environmental impact of products.

Figure 11.13. EU EMAS and Eco-labelling emblems

Eco-label also requires manufacturers to address environmental protection issues and reduce environmental impact.

The eco-labelling process helps to determine the impact on the environment and build an informative link between producers, traders and consumers. However, in eco-labelling the attention is paid to the product and almost none to the production and distribution processes. Consequently, an environment-friendly product can be manufactured in a company causing extensive pollution, or this product can cause damage to the environment or human health after its use.

11.7. EU environmental management institutions[1]

11.7.1. EU directorate-general for the environment

Many EU countries have long environmental protection traditions, which are also reflected in their environmental law. In some countries – for example, in the Mediterranean – environmental protection issues have received less attention. Increasing integration of the EU requires supporting the implementation of the most effective environmental policies at a much larger scale. It is also necessary to ensure a common framework of environmental law, uniform monitoring methodology and standards. These issues are the competence of the European Commission's Directorate-General for the Environment.

The Directorate-General (DG) for the Environment is one of the more than 40 Directorates-General and services that make up the European Commission. Commonly referred to as DG Environment, the objective of the Directorate-General is to protect, preserve and improve the environment for present and future generations. To achieve this it proposes policies that ensure a high level of environmental protection in the European Union and that preserve the quality of life of EU citizens.

The DG makes sure that Member States correctly apply EU environmental law. In doing so it investigates complaints made by citizens and non-governmental organisations and can take legal action if it deems that EU law has been infringed. In certain cases DG Environment represents the European Union in environmental matters at international meetings.

[1] This chapter is prepared based on the materials of the home page of the EU Directorate-General for the Environment – *http://ec.europa.eu/environment/index_en.htm*

General Objectives of DG Environment

In the current crisis, part of our economic activity is coming from the stimulus to demand. But we cannot rely forever on a short-term stimulus. New sources of growth will have to take up the baton – sources of growth that are sustainable. Sustainability means keeping up the pace of reform, targeting our skills and technology on tomorrow's competitiveness and tomorrow's markets; modernising to keep up with social change; and ensuring that our economy can respect the need to protect the European environment, its countryside, its maritime zones, and its biodiversity.

José Manuel Barroso, September 2009
Political guidelines for the next Commission

Environment policy is a fundamental pillar in ensuring green growth in the EU and the shift to a low carbon and resource efficient economy. To serve this purpose these are the general objectives of DG Environment:

- to contribute to a high level of quality of life and well-being for citizens, by aiming to secure an environment where the level of pollution does not give rise to harmful effects either on human health or on the environment and by supporting the Development of a greener and more resource efficient economy;
- to ensure a high level of environmental protection by promoting measures at international level to deal with regional or worldwide environmental problems;
- to preserve, protect and improve the quality of the environment by promoting and supporting the implementation of environmental legislation and the integration of environmental protection requirements into the definition and implementation of other EU policies and activities, with a view to promoting sustainable Development.

The Sixth Environment Action Programme of the European Community (2002-2012) takes a broad look at the environmental challenges and provides a strategic framework for the Commission's environmental policy up to 2012. Every year the Directorate General makes public its priorities for the upcoming year and also publishes a yearly report on the preceding year's policy initiatives.

Figure 11.14. European Union flags outside the Commission building

DG Environment Management Plan for 2010: Mission Statement and Challenges

(by Karl Falkenberg,
Director General of DG Environment)

The main role of DG Environment is to initiate and define new environment policy and legislation, to promote integration of *environmental concerns into other policy areas, and to ensure that agreed policy measures are implemented effectively in the EU Member States. Its mission statement is 'protecting, preserving and improving the environment for present and future generations, and promoting sustainable Development'.*

The political guidelines highlight that the exit from the crisis should be the point of entry into a new sustainable social market economy, a smarter, greener economy, where our prosperity will come from innovation and from using resources better, and where the key input will be knowledge. Conserving energy, natural resources and raw materials, using them more efficiently and increasing productivity will be the key drivers of the future competitiveness of our industry and our economies. Consequently, developing a resource efficient low-carbon economy and stimulating green innovation, growth and jobs are among the main priorities of the EU-2020 Strategy.

Harnessing the environment policy contribution to this goal will mean putting in place the right mix of smart regulation, incentives and market-based mechanisms to foster eco-innovation, sustainable consumption and production and these considerations will underpin all our work. Exploiting the resource potential of waste streams, an action plan for eco-innovation and reviewing the Environment Technology Action Plan, the Thematic Strategy on Natural Resources and the Waste Thematic Strategy will be part of the contribution from environment policy to improve resource efficiency.

The threats from biodiversity loss are becoming clearer and the failure to meet interim goals on biodiversity loss cannot continue. The real value of ecosystems must be recognised and the link between biodiversity conservation and greenhouse gas mitigation should be fully explored. New EU and global targets will have to be agreed in 2010 and a new realistic – but ambitious – action plan for biodiversity will have to be designed and negotiated. Further initiatives are required to protect endangered species of fauna and flora and to address illegal logging and deforestation worldwide. Achieving and maintaining good soil quality is essential in a world where resources are becoming increasingly scarce and there is increased competition for land use from transport, energy, food production and nature preservation and adoption of the Commission proposal by the Council will support this goal. A coherent forest information system for the EU will also be an important element.

With the adoption of REACH, the new law entered into force on 1 June 2007. (REACH is a European Community Regulation on chemicals and their safe use (EC 1907/2006). It deals with the Registration, Evaluation, Authorisation and Restriction of Chemical substances.) The EU has set the benchmark for chemicals policy. But it is the implementation of REACH which will determine its effectiveness and will be a key area of cooperation with DG ENTR

(Directorate-General for Enterprise and Industry) and ECHA (European Chemicals Agency). Registration of chemicals by industry, appropriate evaluation by authorities and substitution of substances of very high concern are key to ensure the safety of chemicals and will also stimulate innovation in the chemical industry. Ensuring a successful co-decision outcome on biocides constitute further important elements to increase the chemical industry's sustainability. Nanotechnology is also rapidly developing and can bring benefits to the environment and contribute to economic growth, but can only flourish if its safety is ensured by a clear regulatory framework. It is more important than ever to focus on using water resources more efficiently, exploiting the potential for water savings and on keeping water clean. Implementing the Water Framework Directive and the Marine Strategy Framework Directive effectively will be essential and will depend on implementation of the urban wastewater and nitrate directives in particular. But it will also require a cross-cutting approach involving support from other sectoral policies.

Air quality legislation brings substantial health and environmental benefits. We need to investigate in more detail the underlying causes of implementation problems in some Member States so that the environmental and health benefits from better air quality are secured. In this context the adoption of the revised proposal on industrial emissions by Council and Parliament is important. In addition, the pending Commission proposal for a revision of the directive on national emission ceilings of certain air pollutants will be re-examined.

Implementation of our legislation maintains environmental progress and ensures that the health and environmental benefits intended from proposals at the time of their adoption actually materialise. Implementation gaps notably in the areas of waste and nature legislation have to be addressed.

Increasingly, progress in environment policy depends on measures taken in other policy areas – such as transport, energy or agriculture – to address the drivers of environmental degradation. We must therefore ensure that environmental objectives are mainstreamed into other Community policies and reflected in the preparation of the future multiannual Financial Perspectives for the 2014-2020 period.

Improving and refining our knowledge base through better information, better management of information systems and the Development of appropriate indicators will help target environment policy as efficiently and as effectively as possible. Following up on our communication on GDP and Beyond, we will work to develop complementary indicators to GDP to measure societal welfare and progress more appropriately. We will work with the EEA (European Economic Area) and the Member States on an implementation plan to see how a shared environmental information system could be put in *place. 2010 is the international year of biodiversity, and among other communication activities, a special focus on this theme is planned.*

Environmental challenges are increasingly global and moving towards a green economy and sustainable production and consumption patterns requires action well beyond EU borders.

The EU is a global leader in developing environment policy and has an important role to play in improving international environmental governance, in particular through multilateral environmental agreements, and ensuring positive synergies with other polices, in particular trade and Development, and the growing significance of the environmental impact of emerging economies. We also need to build alliances and promote global solutions in several areas e.g. in chemicals, in order to capitalise on our experience with REACH.

The 6th Environment Action Programme will be assessed to help assess how policies on air, water, waste, biodiversity and chemicals can be further improved. Environment and health threats from issues such as endocrine disruptors and chemical mixtures will also be addressed.

EC DG Environment

Commissioner for the Environment DG
Janez Potočnik

Office of the Director-General

Directorate A: Legal Affairs and Cohesion
Directorate B: Nature
Directorate C: Industry
Directorate D: Water, Chemicals and Biotechnology
Directorate E: International Affairs
Directorate F: Strategy
Shared Resources Directorate

Figure 11.15. Structure of the Directorate-General for the Environment of the European Commission

EEA's mandate is:
- to help the Community and member states make informed decisions about improving the environment, integrating environmental considerations into economic policies and moving towards sustainability;
- to coordinate the European environment information and observation network (Eionet).

European environment agency

The task of the European Environment Agency (EEA) is to provide sound, independent information on the environment. EEA is a major information source for those involved in developing, adopting, implementing and evaluating environmental policy, and also the general public. Currently, the EEA has 32 member countries.

The regulation establishing the EEA was adopted by the European Union in 1990. It came into force in late 1993 immediately after the decision was taken to locate the EEA in Copenhagen. Work started in earnest in 1994. The regulation also established the European environment information and observation network (Eionet).

Figure 11.16. EEA member countries and cooperating countries

The main clients are the European Union institutions – the European Commission, the European Parliament, the Council – and member countries. In addition to this central group of European policy actors, EEA also serve other EU institutions such as the Economic and Social Committee and the Committee of the Regions.

The business community, academia, non-governmental organizations and other parts of civil society are also important users of our information. EEA try to achieve two-way communication with clients in order to correctly identify their information needs, and make sure that the information provided is understood and taken up by them.

The EEA Information Centre gives individual responses to external requests for information and is open to the general public every working day. The EEA provides assessments and information in the form of reports, short briefings and articles, press material and online products and services. The material covers the state of the environment, current trends and pressures, economic and social driving forces, policy effectiveness, and identification of future trends, outlooks and problems, using scenarios and other techniques.

Summaries of major reports and various articles and press releases are often translated into the official languages of EEA member countries.

In February 2008, the European Commission proposed to establish a European Shared Environmental Information System (SEIS) – a web-based system where public information providers share environmental data and information. SEIS will bring together existing data flows and information related to EU environmental policies and legislation and make it easily accessible to both policy-makers and citizens. A major challenge will be to develop SEIS as a platform for two-way communication, enabling users to upload and share information.

Over the coming years, EEA and Eionet will work together with the European Commission and other stakeholders to implement SEIS. It will be done by building on existing reporting systems and tools (Reportnet), initiatives related to e-Government, the Infrastructure for Spatial Information in Europe (INSPIRE), Global Monitoring for Environment and Security (GMES) and the Global Earth Observation System of Systems (GEOSS).

The EEA Management Board consists of one representative of each of the member countries, two representatives from DG Environment and DG Research of the European Commission and two scientific experts designated by the European Parliament. Among its tasks, the Management Board adopts the EEA's work programmes, appoints the Executive Director and designates the members of the Scientific Committee. The Committee is the advisory body on scientific matters to the Management Board and the Executive Director.

The Executive Director is responsible to the Management Board for implementing the work programmes and for the day-to-day running of the EEA.

The EEA organises its activities in yearly work programmes, overarched by a five-year strategy and multiannual work programme. The current strategy covers the period 2009-2013.

The information provided by the EEA comes from a wide range of sources. A network of national environmental bodies was set up to work with the EEA – the European environmental information and observation network (Eionet) – which involves over 300 institutions across Europe. The EEA is responsible for developing the network and coordinating its activities. To do this, EEA work closely with national focal points (NFPs) – typically national environment agencies or environment ministries in member countries. They are responsible for coordinating the activities of Eionet at national level. The main tasks for the national focal points are to develop and maintain the national network, identify national information sources, capture and channel data and information from monitoring and other activities, help the EEA analyse the information collected and assist in communicating EEA information to end-users in member countries.

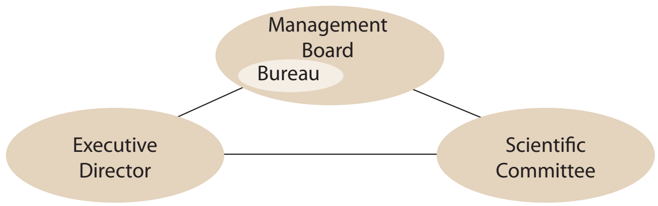


Figure 11.17. EEA governance

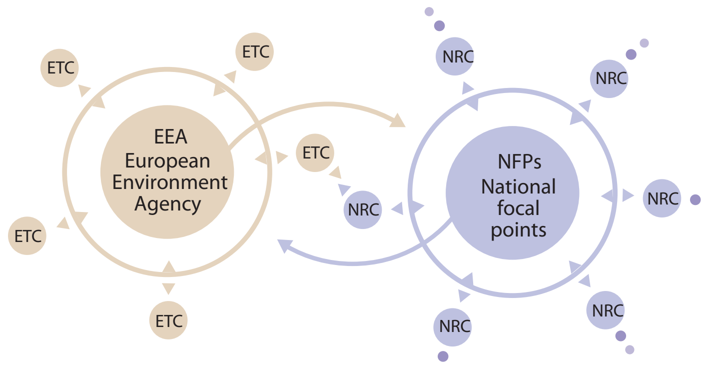


Figure 11.18. European environment information and observation network

Other important partners and sources of information for the EEA are European and international organisations, such as the Statistical Office (Eurostat) and the Joint Research Centre (JRC) of the European Commission, the Organisation for Economic Co-operation and Development (OECD), the United Nations Environment Programme (UNEP), the Food and Agriculture Organization (FAO), and the World Health Organization (WHO). The EEA cooperates closely with these organisations in producing information and assessments for its clients and target groups.

References

Barrow C. J. (1999) Environmental Management. Principles and Practice. London: Routledge.

Bennett M., Sheffield J. P. (eds) (1999) Sustainable Measures. Greenleaf Publishing.

Clapp J., Dauvergne P. (2005) Paths to a Green World. Cambridge: MIT Press.

Duchin F., Lange G. M. (1994) The Future of the Environment. Oxford: Oxford University Press

Klemmensen B., Pedersen S., Dirckinck-Holmfeld K., Marklund A., Ryden L. (2007) Environmental Policy. Uppsala: Baltic University Press.

Kramer L. (2003) EC Environmental Law. London: Sweet & Maxwell.

Leslie P. T. (1999) Environmentalism for a New Millenium. Oxford: Oxford University Press.

Maciejewski W. (ed.) (2002) The Baltic Sea Region – Cultures, Politics, Societies. Uppsala: Baltic University Press.

O'Neil K. (2009) The Environment and International Relations. Cambridge: Cambridge University Press.

O'Riordan T. (ed.) (2000) Environmental Science for Environmental Management. Prentice Hall.

Richard L., Revesz P. S., Richard B. S. (2008) Environmental Law, the Economy and Sustainable Development. Cambridge: Cambridge University Press.

Ryden L. (ed.) (1997) A Sustainable Baltic Region. A Series of Booklets. Vol.1-10. Uppsala: Baltic University Press.

Ryden L., Migula P., Andersson M. (eds) (2003) Environmental Science. Uppsala: Baltic University Press.

Weis P., Bentlage J. (2006) Environmental Management Systems and Certification. Uppsala: Baltic University Press.

Baltic University Programme, Uppsala University. Accessible: *http://www.balticuniv.uu.se.*

Copenhagen Accord. Accessible: *http://ec.europa.eu/environment/climat/home en.htm.*

Ecolabel. Accessible: *http://ec.europa.eu/environment/ecolabel/.*

EMAS. Accessible: *http://ec.europa.eu/environment/emas/index_en.htm.*

EMAS Environmental Policy. Accessible: *http://ec.europa.eu/dgs/environment/pdf/policy_statement.pdf.*

European Community Court. Accessible: *http://curia.europa.eu.jcms/jcms/j_6/.*

European Environment Agency. Accessible: *http://www.eea.europa.eu.*

European Parliament. Accessible: *http://europe.eu/documentation/legislation.*

European Union DG Environment. Accessible: *http://ec.europa.eu/dgs/environment/index_en.htm.*

Eurostat. Accessible: *http://epp.eurostat.ec.europa.eu/cache.*

EU Environmental Management Plan 2010. Accessible: *http://ec.europa.eu/dgs/environment/pdf/management_plan_2010.pdf.*

Intergovernment Panel on Climate Change-IPPC. Accessible: *http://www.ipcc.ch.*

ISO. Accessible: *http://www.iso.org/iso/home.html.*

Natura 2000. Accessible: *http://ec.europa.eu/environment/life/toolkit/comtools/resources/.*

Natura 2000 Barometer. Accessible: *http://ec.europa.eu/environment/nature/natura2000/barometer/index_en.htm#newstat.*

NEC Directive: Member State Country-Profiles(NEC Directive Status Report 2008). Accessible: *http://www.eea.europa.eu/themes/air/nec-directive-member-state-country-profiles.*

UN Sustainable Development Unit. Accessible: *http://www.un.org/esa/desa.*

UNDP. Accessible: *http://www.undp.org.*

UNEP. Accessible: *http://www.unep.org.*

US Environmental Protection Agency. Accessible: *http://www.epa.gov/.*

12. SUSTAINABLE DEVELOPMENT

12.1. Limits to growth

12.1.1. Nature of growth and social development

The development of humanity in the 20th century is characterised by an exponential growth of human population, production and consumption as well as globalisation of numerous processes. Certainly, not everything grows at the same rate; for example, the world oil consumption rate has been slightly decreasing, while that of natural gas – increasing. The nature of selected characteristic changes in the development of humanity is presented in Figure 12.1, which clearly shows that the rates of change are different but the common trend – growth – persists.

The world human population exponential growth started with the Industrial Revolution. The amount of the world industrial production (as an aggregate of the gross national product) demonstrates the trends of exponential growth, even if we disregard the changes created by the fluctuations in the world oil price and the economic crisis. The amounts of pollutant emissions are also growing, and global climate change is the consequence of rising concentration of CO_2 in the atmosphere.

Social development has often been viewed as an achievement. Many communities and peoples, rich and poor, are seeking opportunities for the expansion of their activities to solve vital problems. In the developed part of the world, the necessity of economic growth is justified by the need to create new jobs and provide social security and technical achievements. In developing countries, economic growth appears to be the only way out of poverty. Unless a different solution for world's problems is found, people will look upon development as the main road to a happy future and will do everything to promote growth. Such is the psychological and material motivation for growth.

Obviously, growth can solve some problems; unfortunately, it also causes new ones. This is due to the growth and development limitations. The Earth has its limits. Any physical growth, also population growth, rising numbers of automobiles and buildings, increase in pollution still continues. However, human birth rate, number of cars or buildings and pollution levels are far from the most important limits to growth. The truly vital limits are related to the flows of energy and materials required to sustain people, make cars and construct buildings.

Society and economy depend on constant flows of air, water, food, raw materials and organic fuel, which come from the Earth. However, these flows create the flows of pollution and waste. Limits to growth in fact are limits of global resources and our planet's limited capacity to absorb waste and pollution.

A range of human activities, from the use of mineral fertilisers to urban development, are growing exponentially and can be represented graphically (Figure 12.1).

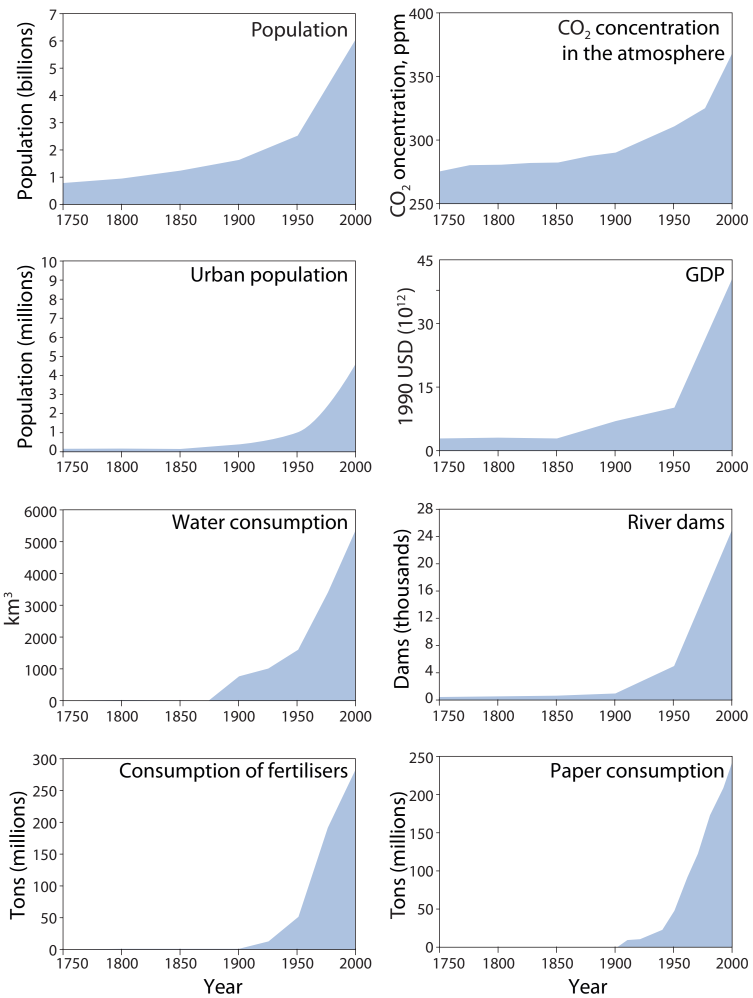


Figure 12.1. Variability of characteristic human development indicators over the last centuries

Exponential growth is the driving force that is responsible for our economy approaching the physical limits of our planet. Rooted in human culture, exponential growth has become an inseparable part of the global system.

The concept of exponential growth, simple on the face of it, can produce surprising results if we look into what it means in our everyday life. It can be illustrated by a Persian legend about the wise courtier who gave his ruler a gift of wonderful chessboard. When asked about a reward, he asked for grains of rice the number of which would be doubled on every next square of the board. One grain on the first square, two grains on the second, and on the tenth square there should be already 512 grains, on the fifteenth – 16 384, while the twenty-first square required over a million grains of rice. Naturally, the ruler's resources of rice were insufficient.

The number of human population and capital are the driving forces that ensure the growth of the industrialised world. Other parameters – food production, use of resources and pollution – also show a trend of exponential growth, although not because they themselves multiply but because of the impact of the human population and capital. Thus, food production and the use of resources and energy have been increasing not because of their structural capacity but because the exponential growth of human population demands ever more food, materials and energy. It is the growing number of population and capital that determine exponential growth. As they increase, they call forth demands for materials and energy which, in their turn, increase pollution emission. This is no arbitrary assumption; it is a fact. Exponentially growing systems have a structural nature, and the mechanism that determines growth is known and comprehended. We have to bear in mind that human population and capital as well as the supporting flows of energy and materials have been increasing for centuries, with a few short-term lapses. Production capital includes equipment, hardware, machines and plants that are necessary to produce goods with the help of labour force, energy, raw materials, land, water, technologies, management and our planet's natural ecosystems. Production capital creates an incessant flow of production.

Changes in the nature of capital can be characterised by exponential growth, exponential decrease or dynamic balance. Just like the number of population depends on demographic changes in the process of industrialisation, so is economy dependant on the process of long-term changes. Production capital grows exponentially and faster than the number of population. Between 1970 and 2008, the world production volume has grown by almost 100%. Such a growth should have produced twice as many industrial goods per person if the number of population had remained constant. However, with the growing human population, the average amount of industrial goods per person has grown only by a third.

If the rate of capital growth exceeds that of population growth, according to the demographic transition theory, an increase in the material standard of living should slow down the rate of population growth. To a certain extent and in some places this is true. However, neither economic growth nor its demographic counteraction is sufficiently fast. In individual cases these factors even facilitate each other. That is why economic welfare dwindles while the number of population remains constant or is on the increase. In a way, this trend is determined by the type of distribution of goods.

While all sectors of world human activity have witnessed huge development, social problems in the world become more vexing year after year:

- every year over two million children below the age of 5 die of easily preventable diseases;
- every day 6000 children die of diseases that are related to the shortage of clean drinking water or poor living conditions;
- about two billion people have no electricity, another two billion suffer from its shortage;
- since 1985, over seven million people in 25 countries have died of AIDS;
- out of 1.2 billion people who live in extreme poverty, around 900 million reside in rural regions; their survival directly depends on biodiversity, level of water pollution and soil degradation.

Economic stratification of the world society is particularly evident. The type of distribution of natural resources as well as human-produced material and non-material wealth has created both very well-to-do people and an extremely destitute part of society. According to the World Bank estimates, an average income of one-fifth of the world's population is less than 0.7 euros per day. 70% of these people are women.

The world's twenty most developed countries, comprising approximately one-fifth of the world's population, mostly are in North America and Western Europe, and Japan, Singapore, Australia, New Zealand, the United Arab Emirates and Israel also belong to this group. Over three billion live in the poorest countries in Africa and Asia. The gap between these two worlds is growing. The annual income level of an average person in a world's affluent country is over 100 times higher than that of an average resident of a low-level income country. The inequality gap is even more striking at the level of individuals. The total wealth of the world's 200 richest people amounts to 0.7 trillion euros, which is more than possessed by the three billion of world's poorest people together.

The lifestyle of the well-off people has an essential impact on the consumption of the world's resources. For example, the USA with its 5% of the world's population consumes about one-fourth of the world's industrial goods and produces nearly half of industrial waste. An American citizen's average daily consumption comprises 450 kilograms of raw materials, including 18 kilograms of fossil fuels, 12 kilograms of agricultural produce, 10 kilograms of timber and paper, and 450 litres of water. Annually, Americans dispose of 50 million tons of paper, 67 billion bottles, 18 billion pampers, 2 billion razor blades and other resources.

The economist Jeffrey Sachs, Director of the United Nations Millennium Project, points out that eradication of extreme poverty by 2025 is feasible if the developed countries donated just 0.7% of their GNP towards aid to developing countries. These funds should be used on vaccinating children against infectious diseases, ensuring general accessibility to primary education, family planning services for those who need them, provision of drinking water and sanitation, food for the famine-stricken, and for strategic micro-loans to self-employed people. This sum – 10 billion euros a year – is much bigger than the current donations; however, the question is about the priorities. At present, military expenditure exceeds 0.7 trillion euros per year, which amounts to the annual income of half of the world's population. The price of an aircraft-carrier is tantamount to the sum that all the industrially developed countries donate to aid developing countries in ten years.

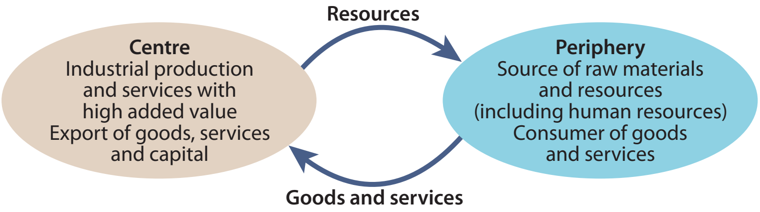


Figure 12.2. Simplified scheme of division of labour in globalised economy: structures of centre and periphery

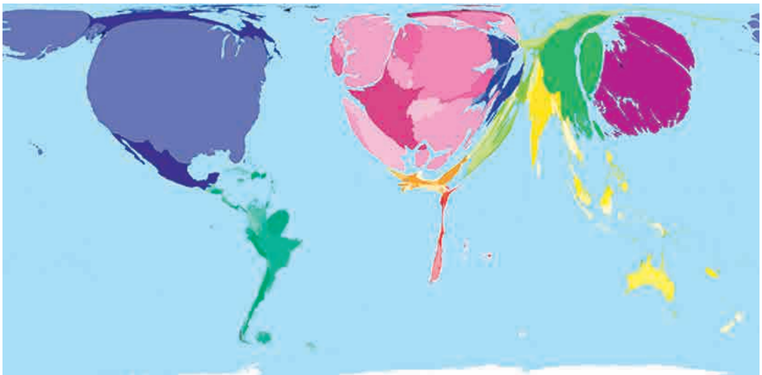


Figure 12.3. Distribution of welfare: countries of the world. The size of the countries on the map is in proportional to their per capita GNP

In industrialised countries, economy develops more rapidly, and economic growth is systematically in progress. Economic stagnation in developing countries is determined by a number of causes, including systematic injustice and oppression, especially concerning the poorest layers of society. It is much easier for a developed country to economise, invest and accumulate capital not only because developed nations have a better control of markets, develop and purchase new technologies and manage resources. During the previous centuries of growth, the developed countries have accumulated more capital which can now be multiplied even more efficiently. However, providing for basic needs in the future is feasible without the depletion of the existing reserves by economising resources and preserving the volume of investments. A smaller population growth in more developed countries enables them to allocate most of production capital to industrial investments and diminish investments in the service sphere, particularly in health care and education. Rapidly developing countries and economies cannot afford it.

In developing countries, there are considerable restrictions to capital growth due to growing population and other reasons. The surplus value that could be used for investments is allocated, luxury of the power elite, payment of external debt or excessive militarisation. Conducive to poverty is corruption, low level of education, and mismanagement, while population is placed under the growth model that increases the number of population and prevents the growth of welfare. The structure that relates the number of population to capital ensures the principle of the global economy model which can be illustrated by an ancient proverb: the rich become richer, the poor beget children. Notably, these features of the system are by no means accidental. The system has been created to produce precisely such results, and the process will continue if the structure is not subjected to well-considered changes. Population growth impedes the growth of production capital, calling forth ever-increasing demands of schools, hospitals, resources and basic goods, in this way diminishing the part of industrial produce that could be invested in production. Poverty makes the growth of human population endless, forcing people to live without quality education, health care and access to family planning. The only choice or way to live on is a big family and a hope that children will help to raise the family income or serve their family as labour force.

Poor people need food, shelter and material values. The well-off people use material growth in order to satisfy other needs, real but non-material: boosting their own recognition, self-confidence, unity, personality. While we are rapidly approaching the limits of our planet, unfortunately, discussions about the limits to growth in many cases does not have any influence on these people.

12.1.2. Limits to development

Considering the self-regeneration potential of population and industrial capital, they can be viewed as the driving forces of the world system's exponential growth. Society promotes their growth in every way for the purpose of ensuring production.

The number of population and capital have a potential that ensures their production and reproduction. This potential cannot be realised without a continuous supply of energy and materials or without a continuous removal of pollution.

People need food, water and air for their growth, sustenance of their bodies and procreation. Production, in its turn, needs energy, water and air as well as huge amounts of minerals, chemicals and biological material to produce goods, to facilitate human life, to maintain the system of production and ensure its increase. In accordance with fundamental laws, people – and plant-consumed materials and energy do not vanish. Materials can be recycled, or they turn into waste and pollution, whereas energy is dispersed as heat.

Materials and energy consumed by population and capital are extracted from the Earth, returning waste and heat to the Earth instead. There is a constant flow from the global sources of energy and materials via economy to the environment, where waste and pollution are accumulated. However, there are definite limits to the increase rate of the use of materials and energy and the resultant production of waste, so that it would not harm people, economy or the Earth's absorption processes, regeneration and self-regulation.

All resources that people use – food, water, iron, phosphorus, oil and thousands of others – are limited in terms of both their sources and resulting emissions. These limits are complex, since both the sources and emissions constitute part of a dynamic, interrelated and single system – the Earth. There are short-term limits, for example, the amount of oil in a reservoir stored for a specific purpose; there are also long-term limits, for example, the amount of oil in the Earth. Sources and discharges can interact, while the planet can, through natural processes, influence both the sources and pollutant emissions. Thus, soil can be both a source for food production and a recipient of acidic precipitations resulting from air pollution. The capability of soil to perform a particular function largely depends on the performance of other functions.

To introduce some clarity in this complexity and to define long-term or equilibrium limits to development, the World Bank economist Herman Daly has offered three simple regularities:

1) for renewable resources – soil, water, forests, fish – the rate of long-term use must not exceed that of their regeneration. For example, catch of fish is viable if the fishing rate is in balance with the reproduction of the remaining fish population;
2) for non-renewable resources – fossil fuels, high-concentration mineral ores, natural underground water – the rate of their balanced use must not exceed that of the use of renewable resources to replace the non-renewable resources. For example, the use of oil fields would be balanced if part of profits were systematically invested in the production of solar panels or planting trees. This means that when oil reserves are exhausted, the flow of renewable energy will be sustained;

Figure 12.4. Forest gutted by fire (summer of 2009, Greece)

3) the rate of pollutant emissions must not exceed the rate of absorption of pollution or the rate of rendering it harmless to the environment. For example, a discharge of wastewater into a lake or a river is admissible only if the rate of discharge corresponds to the ecosystem's natural capability of self-purification.

There is plenty of evidence to support the idea that development and growth take place at the expense of irreversible depletion or degradation of the existing resources.

The nature of human development demonstrates that people do not use the Earth's resources and possibilities of development in a balanced way. Soil, surface waters and groundwater, wetlands, nature and the environment are degrading. Even in the places where renewable resources seem to be plenty (for example, North American forests or European soils), the quality and diversity of these resources and their potential of survival can be questioned. Mineral and fossil fuel resources are running out. Moreover, there is no plan and no satisfactory capital investment programme to sustain industry when fossil fuel will have run out. Pollution is accumulating – pollution emission has started to overtake the flow of substances in their biogeochemical cycles, and the chemical composition of the atmosphere is changing.

In 1972, an interpretation of the nature of as well as limits to human development and, what is more important, modelling the consequences of exceeding these limits and guidelines for action were offered by Dennis Meadows, Donnella H. Meadows and Jørgen Randers, authors of the book *Limits to Growth*. The character of human economic development and the approach to the solutions of environmental and social problems confirm that the offered prognoses and models are correct and that it is necessary to change the character of development.

If only a single resource or several resources run out while there is sufficient amount of others, we might presume that growth will continue by replacing one resource with another (although there are limits even to such replacement). However, if many sources are depleted and pollution flows are overloaded, there is no doubt that human consumption of materials and energy has gone too far. Humanity will have overstepped the limits of sustainable development.

These limits apply to the amount of raw materials that has been used up over a given period of time. Humanity has accelerated the consumption of resources not only in terms of space, rate of flows or limits; this is also true concerning human population growth.

12.1.3. Beyond the limits

The modelling of humanity's development is based on the assessment of the volume of the existing and available resources, correlating their changes with the number of population and capital. To achieve this aim, it is necessary to turn from the static analysis of a single factor in time to a dynamic analysis of the whole system.

In the majority of the world countries, capital grows faster than the population, although in some other countries a reverse process can be observed. In some countries the growing economy allows to slow down the birth rate, while in other countries poverty and social inequality increases mortality. People who have become richer demand more goods, more energy and cleaner air. Poor people fight for clean water, agricultural land and firewood. Some technologies increase pollution flow, others decrease it. The reserves of non-renewable and some renewable resources are running short, while the remaining reserves are used more intensively and more efficiently.

The modelling of the nature of human development (Figure 12.5) demonstrates that, with the existing trends of development, even with sustained technological progress and expanded accessibility of raw materials and resources, an overshoot of limits to growth and catastrophic drop in welfare can occur already in this century. A possible consequence of this is decreased industrial production and food availability, as well as a decrease in the number of population.

The number of human population, the volume of the use of resources and the volume of consumption in developed countries continue to grow like it was in the 20th century, until the growth rate is decreased by the availability of non-renewable resources and their rising price. Eventually, this leads to the decrease in production volumes and allocation of investments to support resource flows, whereas the decreased availability of investments in other sectors of economy leads to the decrease in industrial production and services. As the volume of industrial and food production diminishes, the availability of health services shrinks, and, as the environmental pollution increases, the life span falls into decline.

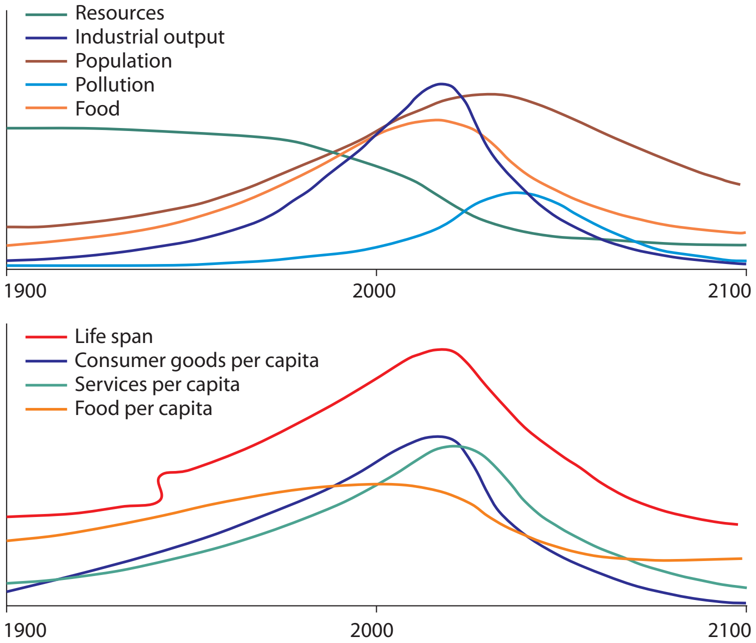


Figure 12.5. Possible nature of social development at the existing consumption rate

Over the last century, modern society has witnessed a rapid human population growth and has made remarkable achievements in the technological and social spheres: from the steam engine to democracy, to the computer and corporations. The achievements have enabled economy to overstep the visible physical and material limits and sustain continuous growth. This is especially true about the last decades, when the full-scale industrial culture was associated with the development of consumer society and implanted in human minds as an idea of unceasing growth. To most people this makes the idea of limits to growth inconceivable and unacceptable. Politically, limits should not be mentioned; economically, they are inconceivable. Society tends to dismiss the possibility of limits and tries to replace it with a possible fight for the improvement of technologies and the development of free market. Meanwhile, the results of social growth modelling show that the existing way of human development has exhausted itself.

- If the tendency of growth for the world population, industry, pollution, food production and consumption of resources continues, the limits of our planet will be reached approximately within this century. Use of more common resources and numerous types of pollution have already exceeded the rates that can be physically balanced. Unless a considerable decrease in the flows of materials and energy is achieved, the coming decades will see an uncontrolled decrease in per capita amount of food, energy and industrial produce. As a foreseeable result, there may be a sudden and uncontrolled decrease in population and volumes of production.
- However, this decrease is not unavoidable. It is feasible to diminish the tendencies of growth and create conditions for environmental and economic stability that can be well balanced even in a long-term future. The global equilibrium should be created with a view to satisfy every person's basic material needs and provide equal possibilities of self-development for all.
- The existence of a balanced and sustainable society is technically and economically viable, and it is more desirable than a society that seeks to solve its problems through continuous expansion. Transition to a balanced and sustainable society requires carefully balanced long-term and short-term goals, preferring sufficient provision for life, equality and quality instead of the volume of the aggregate product. It takes more than just labour productivity, more than just technology; it also takes maturity, empathy and wisdom. Should people opt for the second option, the sooner they start acting, the better are the prospects for the success.

12.2. Concept of sustainable development

Today the concept of sustainable development is not just an opinion on how humanity as such and also each community and society should develop; it is principally a set of opinions about the model of a society that can ensure its own existence. The concept of sustainable development includes physical conditions, political conceptions, the notions of the quality of life or welfare and an optimised influence on the environment to ensure that the resources are equally accessible to all generations. The concept of sustainable development is based on the understanding of three notions: development, needs of society and needs of the future generations. Within the concept of sustainable development, the notion 'development' includes not only growth (of production, gross national product, welfare) but also the development of social and economic spheres that guarantees the preservation of natural ecosystems and the human living environment. Thus, the concept of sustainable development not only looks at short-term processes (to satisfy the current needs) but also aims at ensuring equal possibilities for the next generation.

A society that would exist eternally could be deemed sustainable. With this perspective, the concept of sustainable development is a frame of reference that aims at influencing the future of humanity and the existence of society. So far, social development models have been unsuccessful and have proved either their obvious inability to ensure social development, or they have not managed to take into account essential differences between various regions of the world. Re-evaluation of social development conceptions largely depends on understanding the impact of social development on the environment and the urgency of environmental protection. Many arguments support the necessity to re-evaluate the models that have been practiced up to now.

- Development, especially in Western societies, is understood as human domination over nature (illustrated by the phrase 'man – the crown of creation') and the use of its resources for the development of production. This attitude ignores the role of nature and ecosystems in providing for the development of humanity; it also ignores the value of nature *per se* and that other forms of life and living organisms may have needs and, most importantly, a right to exist.
- The main priorities in the development model that dominates in Western societies is economic growth and consumption, the latter being the principal parameter of an individual person's and humanity's welfare. In conformity with this concept, social welfare is the standard of life – the part of income that is used to purchase goods and services. This model of development, based on individual consumption, eventually leads to huge inequality in terms of income and welfare even within a single country (especially because of the cyclic nature of free market economy), to say nothing of the arising differences between different regions of the world. The inevitable differences of such welfare model result in social tension, military conflicts and social instability.

- The consumer society's development based on the increase in resources unavoidably leads to the increase in consumption and industrial waste (pollution) and depletion of resources. Due to the growth of production and increase in consumption, the nature of environmental problems over the last decades has changed.
    - *Environmental pollution sources – point or non-point.* In the past, point sources of pollution were common, for example, pollutant discharge into the air or water from a plant, leakage of hazardous substances as a result of an accident or from a landfill. Gradually, the harmful influence on the environment became less concentrated, and non-point sources of pollution started dominating, such as agricultural runoff of nutrients, domestic use of chemicals, pollution arising from automobile exhausts. The consequences of point source pollution can be tackled by restrictive measures; dealing with the problems created by non-point sources is much more complicated and takes more time to achieve positive result.
    - *Scale of environmental problems – local, regional or global*. Until quite recently, pollution was of a local nature, usually around the point source of pollution. Later on, it transpired that pollution can impact regions, crossing the borders of countries, for example, acid rains and eutrophication. At present the most topical environmental problems are of a global scale. The larger the scale of the problem, the more difficult it is to tackle it, as it requires international cooperation.
    - *Duration of environmental problems – short-term or long-term*. In many cases the harmful impact on the environment is short-term if the activity of the source is limited in time. Such were the cases of air pollution from district heating plants or water pollution from small inhabited places. Currently, most of the environmental problems are long-term; they do not disappear immediately even after the source is liquidated. Persistent organic compounds, compounds of heavy metals or radioactive contamination can affect the environment long after the pollution has stopped. An example of this is the eutrophication of the Baltic Sea, the reduction of which is going to take several decades, even if the nutrient release were totally stopped.
    - *Complexity level of environmental problems – simple or complex*. Many environmental problems are becoming more and more complex. A single enterprise may use

hundreds of various chemical substances and many of them can be environmentally persistent. Also, consumer goods can affect the environment in more ways than one. Not just various substances, even different sectors of industry, have a synergistic influence on the environment. The more complex the environmental problem is, the more complicated it is to understand and tackle it.

- The consumer society's model of development ignores the fact that it is unviable to globally sustain the type of production which consumes resources and degrades the environment and which ensures the lifestyle of the world's most developed countries. Already now, when the desirable consumption level has been attained in a relatively small number of the world countries, all the ecosystems of the planet cannot absorb the human-created pollution, like in the case of greenhouse gas emissions causing climate change. It is obvious that the Earth's resources are insufficient to ensure the existing consumption level in West European and North American countries over a long period of time, not to speak of ensuring such a volume of consumption for all people in the world. Similarly, the consumption rate increase is unviable in the future, even if we do not take the technological progress into account.
- The understanding of the character of the development of the so-far existing Western societies was based on the idea of limitless development and growth. Now we have to admit that there are limits to economic growth. They are determined by the planet's carrying capacity, accessibility of resources whose amount is limited, and the capacity of the planet's ecosystems to absorb pollution. Although technological progress can, undoubtedly, increase the efficiency of how resources are used, it is impossible to overcome these development limits. Hence, the development of humanity must guarantee a balance between the planet's ability to sustain human existence and the desired lifestyle.

12.3. Formation of the concept of sustainable development

The necessity of sustainable development was first declared in Stockholm in 1972, at the UN Conference on the Human Environment. The contemporary understanding of sustainable development is based on the idea that was voiced in the 1987 Report by the

UN World Commission on Environment and Development: Our Common Future: 'Sustainable development is development that meets the needs of the present generations without compromising the ability of future generations to meet their own needs.'[1] The concept of sustainable development, its agenda and solutions for its implementation today are important tasks of the UN. The UN Conference on Environment and Development in Rio de Janeiro, 1992, was dedicated to the above issues. Two important documents were adopted at the conference: 'Declaration on Environment and Development' and action programme for the 21st century 'Agenda 21'.

The strategy 'Think globally, act locally' highlights the idea that no global action is feasible without purposeful local steps. Many countries of the world have recognised the necessity to design their development strategies in such a way that not only the rates and prospects of economic development as well as quality of life are sustained but also environmental degradation and over-consumption of resources are eliminated. Thus, the concept of sustainable development became a frame of reference that could influence the activities of the contemporary society and the development of the future society. The sustainability of the development of the world countries was evaluated in 2002 at the UN World Summit on Sustainable Development in Johannesburg, the Republic of South Africa.

An updated and more elaborated definition of sustainable development is provided in the European Union Sustainable Development Strategy:

Sustainable development means that the needs of the present generation should be met without compromising the ability of future generations to meet their own needs. It is an overarching objective of the European Union set out in the Treaty, governing all the Union's policies and activities. It is about safeguarding the earth's capacity to support life in all its diversity and is based on the principles of democracy, gender equality, solidarity, the rule of law and respect for fundamental rights, including freedom and equal opportunities for all. It aims at the continuous improvement of the quality of life and well-being on Earth for present and future generations. To that end it promotes a dynamic economy with full employment and a high level of education, health protection, social and territorial cohesion and environmental protection in a peaceful and secure world, respecting cultural diversity.[2]

---

1 Our Common Future (1987) Oxford: Oxford University Press.

2 EU sustainable development strategy. Accessible: *http://ec.europa.eu/environment/eussd/*

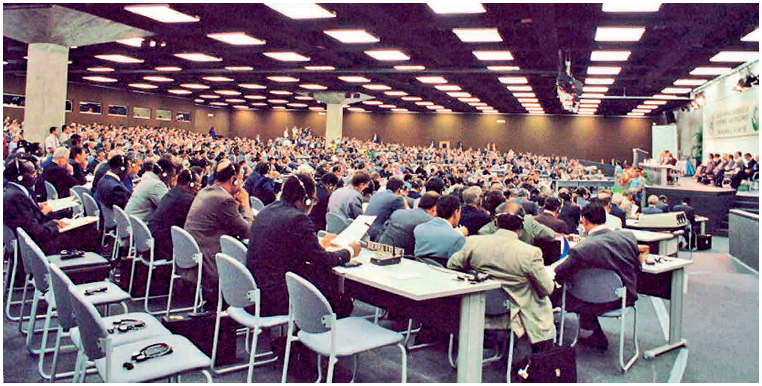


Figure 12.6. Boutros Boutros-Ghali, Secretary General of the UN, opens the Conference on Environment and Development in Rio de Janeiro, 1992

The concept of sustainable development is based on the necessity to optimise economic development and social system, as well as the impact on the environment and the use of resources. This model of development has to ensure the sustainability of economy, environment and the social sphere in time and space (Figure 12.7). The three basic spheres requisite for the humanity's existence today are the following: viable economy, harmonious society and healthy environment. These are also the desirable external prerequisites for the development of an individual. Sustainable development implies that each economic, social or environmental issue must be solved in such a way that the adopted decision is favourable, or as little unfavourable as possible, for the development of other spheres.

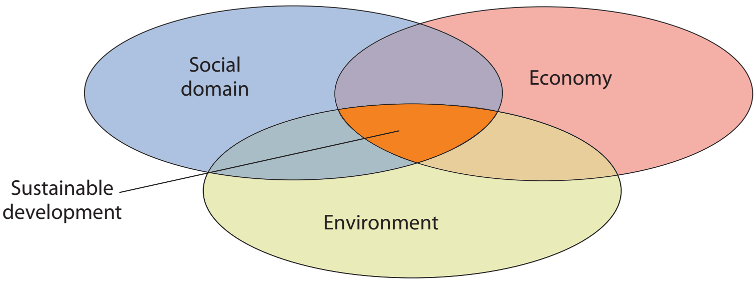


Figure 12.7. Sustainable development of the environment, economy and the social domain

The main tasks of sustainable development are the following.

- Preservation of resources, i.e. ensuring the availability of resources for humanity's development not only to the present but also to the future generations. This involves the necessity to implement an agenda and policies that aim at raising the efficiency of the use of non-renewable resources, their replacement with renewable resources, at the same time

Sustainable development goals and principles have become guidelines for the adoption of corresponding decisions concerning economy, policy and environment protection with the aim to:

- restrict human impact on the surrounding natural environment and prevent further overstepping the self-regeneration capacity of the environment;
- maximally decrease the consumption of non-renewable resources and ensure a more extensive use of renewable resources;
- safeguard and protect nature to ensure the preservation of biodiversity;
- promote economic development to satisfy human needs, improve the quality of life and ensure fair distribution of the world wealth;
- create a decision-making and management system that is conducive to citizens' participation in the decision-making process.

preserving biodiversity and protecting the genetic potential of species. The ways of carrying out this task are well known, for example, the development of alternative energy sources, recycling of industrial and other waste, development of new, environment-friendly technologies.

- Balanced development of the human-created (anthropogenic) environment and the natural environment, related to, for example, the necessity to preserve the productivity of agricultural lands or optimise the use of urban territories and traffic flows.
- Ensuring the quality of the environment that allows social development by discontinuing or restricting the processes that degrade the environment and exert an adverse impact on the self-regeneration of ecosystems, and by eliminating processes that may be hazardous for human health and lower the quality of life. Besides, it is necessary to restore the degraded environment at the same time.
- Ensuring social equality. Sustainable development cannot be achieved without ensuring social equality in individual countries as well as among countries by preventing the growth of income inequality and ensuring the kind of development that reduces social inequality.
- Social participation in the management of the state and the environment clearly shows that sustainable development must enjoy an overall people's support. Sustainable development is unattainable without a change in the citizens' attitude to consumption and use of resources. Social transition to sustainable development can be ensured only if there is a political commitment and transition from a socio-economic society based on the overuse of the existing resources and unequal distribution of benefits to a society based on social equality, considerate use of resources and efficient management. It is also clear that such social changes cannot be achieved by administrative reforms; instead, they must be introduced and supported by the grass roots. The objective of sustainable development is to bring about changes in the people's attitude to values by ensuring greater participation of citizens in political decision-making and social management.

Sustainable development can be attained by solving the above five tasks – implementing social planning within the framework of market economy without stipulating the instrumental political system.

Sustainable development is functioning when the aggregate stocks of the Earth's capital remain undiminished or continue growing.

Sustainable development involves continuous development and preservation of all forms of capital, as humanity's existence and welfare depend on them now as well as in the future. Since the Earth's aggregate capital consists of the totality of these capitals, there is a possibility that the aggregate capital stocks can increase even if one form of capital diminishes. For example, the natural capital can decrease, while the economic growth may be sufficient to ensure the growth of the aggregate capital.

This is why the mutual substitution of capital forms can be described as two approaches to sustainable development:

- strong sustainability is achieved if none of the sustainable development capital forms is depleted. This approach is not based on the substitution principle and does not admit of the substitution of the natural capital with the human-made capital. As a result, the approach creates problems when the critical limits of the natural capital are determined. The denial of substitution of capitals, in turn, creates a situation when certain forms of capital are endowed with an absolute value which is higher than that of others;
- weak sustainability is based on the assumption that welfare and sustainability do not depend on a certain form of capital; instead, it is ensured if the Earth's aggregate capital stocks grow. This approach permits the mutual substitution of different forms of capital. Consequently, it would admit of logging Brazilian virgin forests to develop green farming in the vacated territory, or to invest the procured funds in the development of human capital. In this case, the problem arises as two incomparable categories – forests and people – are compared, determining their value and level of substitution. Weak sustainability is also based on the analysis of gains and losses, which admits of mutual substitution.

The aggregate stocks of the Earth's capital can be classified into three principal forms:

- economic (human-made) capital, which conventionally comprises equipment, technology, buildings and infrastructure, and which is used for producing goods and providing services;
- social capital, which is related to human welfare both socially and individually. It consists of social norms and formal and informal structures that ensure access to resources, helps to solve common problems and enhances social unity. It is based on human spiritual and physical health, education, motivation, talent, skills and abilities;
- natural capital, which includes all ecosystems and natural resources (renewable and non-renewable). Besides the conventional natural resources (timber, water, energy, minerals), the natural capital comprises also such values of nature that are difficult to express in monetary terms – biological diversity, species and ecosystems that ensure ecosystems services (for example, purification of air and water).

12.4. Guiding principles of sustainable development

In the process of planning, implementing and evaluating the sustainability of development, a number of basic principles have been worked out. Some of these are socio-ecological principles, which clearly outline regularities of development and enable precise identification of development goals. There are different transition routes to sustainable development, and mistakes are possible; however, having a precisely defined goal is prerequisite.

The advantages of socio-ecological principles lie in their assessment of sustainable development from a systemic perspective and consideration of activities in succession from the very beginning.

Among the basic principles of sustainable development, the most important are four ways of sustainability that give answers to the question 'how to act?' to ensure social development.

- **Diversity** should be viewed as a prerequisite for the development of any system (including society). Biological diversity, economic diversity and cultural diversity underpin the capacity of the biosphere and society to sustain their dynamic stability. Innovation and adaptation to new conditions are feasible if there are different approaches and alternatives to development, which can serve to form new, stable social systems. To enhance long-term stability, as often as not the most suitable strategy is the diversification of development.
- **Subsidiarity or self-government** implies all possible functions at the lowest possible level of management. External assistance or directives are acceptable only if they help to perform the delegated functions without endangering the autonomy of the subsystem. Self-government is closely connected with social responsibility and social security, and it can be applied to all spheres – politics, administration, entrepreneurship, technical systems, management of material flows in economy. This principle does not provide clear instructions; instead, it urges to seek the optimum solution between autonomy and integration in more comprehensive systems. The implementation of the principle of self-government stimulates individual participation and the proactive attitude of local governments with the aim to improve and manage their life, thus promoting democracy.
- **The principle of cooperation** emphasises the significance of horizontal, non-hierarchical interactions. This model of cooperation is based on common objectives and rules and, as a rule, is open: participants can join in or opt out. Cooperation networks ensure the exchange of experience and information, promote mutual support, stabilise systems as well as facilitate competition – participants can choose another, more attractive cooperation network. This is why a vitally important feature of cooperation networks is their ability to adapt to novelty and focus on the participants' needs.
- **The principle of participation** or involvement corresponds with the basic ideas of democracy and forms the grounds for diversity of approaches. It can play an essential role

in avoiding conflicts. It is of utmost importance that all the parties involved in the solution of a problem should participate at the initial stage of defining the problem and identifying the possible alternatives. Participation facilitates responsibility and motivates people to make their contribution towards the implementation of the adopted decision. Besides, participation claims the participants' time and interest, openness of the institution involved and, as a rule, more time and funds than the accurate hierarchic decision-making. The chosen procedure may pose a risk that the decision may not comply with the experts' opinion, while the principle of participation commands respect for diverse interests and opinions.

Although there are various basic principles of sustainable development, their application adds a practical dimension to adopting responsible decisions concerning economy, policy and environmental protection.

Assessing the implementation of sustainable development, the issue of using the concept of sustainable development in countries with different economic and social regimes is particularly important. Up to now, the most extensive research pertains to the perspectives of sustainable development in industrially developed countries. Although the number of such countries is relatively small, their complying with the basic principles of sustainable development is particularly topical due to the high level of consumption which, in interaction with the free market economy and globalisation processes, is, in fact, one of the principal causes of global environmental and development problems. At the same time, precisely the industrially developed countries display the understanding of the necessity of sustainable development. A strategically important trend of sustainable development in industrially developed countries is the concept of dematerialisation – decoupling economic development from material consumption or ensuring the growth of well-being against the background of diminished needs of material consumption and use of resources. The situation in industrially developed countries is considerably different from the situation, for example, in Africa, most of Asia, in South America as well as in many European countries. The people's desire to reach the level of welfare of industrially developed countries as fast as possible makes the necessity to decouple economic development and material consumption even more topical. Even so, sustainable development issues in the developing countries are related to the solution of the problems caused by the backlash of free market economy and globalisation, which cannot be solved locally.

12.5. Ecological footprint[1]

Figure 12.8. Ecological footprint

Ecological footprint is a means for measuring the flows of energy and materials in a given economic system (country, city, household), and the values are converted into the land area necessary for nature to maintain these flows.

To satisfy human needs for goods and services, the use of natural resources creates environmental pollution and waste. Ecological footprint is an indicator of sustainable lifestyle which shows how much land is required to satisfy people's needs.

Mathis Wackernagel, one of the author's of the ecological footprint concept, defines it as the area of land and water, converted into hectares, necessary to produce the products that an individual or a population, or an activity has consumed and to absorb the pollution formed in the life cycle of the products, using the existing technologies and experience of resource management. For example, the ecological footprint of a given country is the total land area in hectares that is necessary to produce food, goods and services consumed by its population and to absorb waste and pollution that have arisen in the full life cycle of these goods. The ecological footprint allows to measure and analyse the consumption of natural resources, volume of created waste and regenerative capacity of nature. Unlike other indicators (of impact on the environment), the ecological footprint also shows the pressure on the environment that our consumption causes in other countries, because the pressure on the environment from producing imported goods is in the country of origin.

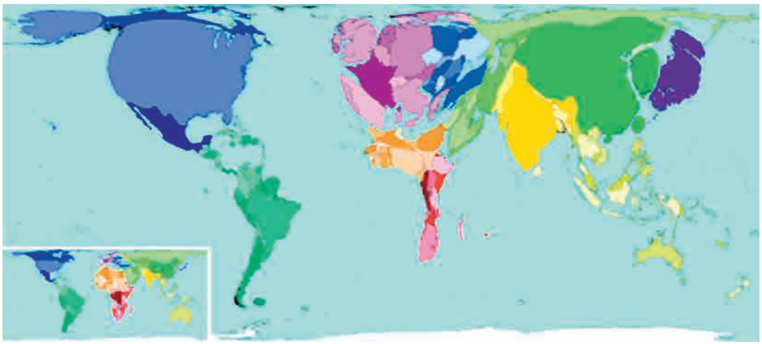


Figure 12.9. Ecological footprint in world's countries

People consume resources and ecosystem services from different countries of the world, and their ecological footprint is the totality of these territories irrespective of their whereabouts. The map shows territories of countries by their ecological footprints in proportion to the total world ecological footprint. The largest ecological footprints are those of the USA, China and India. However, the largest

[1] At preparation of this chapter contribution of J. Brizga is acknowledged.

ecological footprint per capita is in the USA, while in China and India it is three times smaller than the world average.

The ecological footprint as an efficient indicator of the environment and development is rapidly gaining attention. It was the ecological footprint that the European Environment Agency in its reports of 2005 and 2007 on the environmental situation in Europe used as one of the indicators. This graphical representation of human impact on the environment allows to compare different countries and also the dynamics of indicators within a particular country.

At present the ecological footprint is widely used in the world to characterise environmental sustainability and form public awareness of environmental issues. Several countries (Switzerland, United Arab Emirates, Japan, Belgium, Ecuador and France) have included the ecological footprint in their national statistics and carry out these calculations regularly. In the United Kingdom, the ecological footprint is extensively used in the environmental impact assessment, including that of the local development scenarios.

Bioproductivity is an essential parameter to assess the ecological footprint as an indicator of the consumption of natural resources in global hectares. It shows the planet's ecological capacity or biological productivity. In this way, the balance reflects the demand (ecological footprint) on the one hand and the supply – bioproductivity that consists of various bioproductive territories – on the other hand. These territories are:

- cropland,
- pasture,
- forest,
- sea,
- territory allotted to the preservation of biodiversity.

12.5.1. Ecological footprint calculation methodology

National bioproductivity is the whole of all the territories (including those not used because of economic, nature protection or other reasons). Each bioproductive territory is converted into global hectares, multiplying this territory by the equivalence factor of the given territory and the corresponding productivity factor.

This calculation can be expressed with the following formula:

$B = T \times EF \times PF$,

where

B – bioproductivity, ha_g,

T – territory, ha_g,

EF – equivalence factor, ha_g,

PF – productivity factor, t/ha.

As to the ecological footprint, its calculation begins with creating a matrix of the type of land use which includes, apart from bioproductive territories, the infrastructure and territories that are necessary for the absorption of carbon dioxide. Consumption categories within this matrix are food, dwelling, transport, consumer goods and services. The matrix of the land use type shows the kind of land use necessary to ensure the production of goods and consumption for a given number of people and consumption patterns. The number of population and information about various consumption categories are used to calculate the average annual consumption per person. The consumption is calculated by adding up the data on import and national production and subtracting export. The term 'seeming consumption' has also been introduced, which is different from the real household consumption since it includes the resources that are used in export and excludes the resources that have been invested in the imported goods (for example, energy that has been consumed to produce tomatoes in Spain and transport them to Latvia).

The methodology for ecological footprint calculation stipulates the parameters of the data used, re-calculation factors, boundaries of research and dissemination of results.

The territory of land necessary to produce the annual consumption of goods is attributed to a category of bioproductive territory (cropland, pasture, forests, fishing and built-up territories) which is multiplied by the equivalence factor to calculate the ecological footprint in global hectares:

$$EFp = \frac{C}{PF \times EF},$$

where

EFp – ecological footprint, ha_g,

C – consumption, t/g,

PF – productivity factor, t/ha,

EF – equivalence factor, ha_g/ha.

The methodology for ecological footprint calculation is based on the assessment of the area of bioproductive territory. Global hectares (ha_g) is the bioproductive territory (total area of the Earth is 11.2 billion hectares) with the world's average productivity. Instead of the volume of the produced biomass, productivity in this case is the maximum potential of agricultural production. This makes a hectare of fertile soil equal to several global hectares. Global hectares have been normalised so that the total number of hectares of productive territory would be the same as the quantity of global hectares. Global hectare is a means to compare the ecological footprints and bioproductivity of different countries.

Equivalence factor helps to convert the given bioproductive territory (cropland, pasture, forests, developed and marine territory) into global hectares. For example, cropland is more productive than pasture and its equivalence factor is correspondingly higher.

Table 12.1. Land use equivalence factors (ha_g/ha)

Land use	*Equivalence factors (ha_g/ha)*
Cropland	0.50
Forest	1.33
Built-up territory	2.64
CO_2 absorption	1.34

Productivity factors show the fertility of a particular type of bioproductive land in different countries. For example, owing to its high fertility of grass, one hectare of pasture in New Zealand can yield more meat than in Latvia. Such differences may be related to the local peculiarities, such as precipitation, quality of soil or particular management.

The ecological footprint is not a comprehensive indicator that would reflect all of the environmental pressure. It does not directly reveal chemical pollution, soil erosion, consumption of water resources, nutrient runoffs and sensitivity of forests to pests or storms, or other factors that can have a considerable impact on bioproductivity. However, the majority of possible impacts will affect productivity and are reflected in the ecological footprint and bioproductivity. The ecological footprint does not reveal the depletion of non-renewable resources (oil, coal, mineral resources) because the regenerative capacity of resources in the calculation functions as the delimiting factor. The impact of fossil and mineral resources on the environment in the ecological footprint calculation appears only in relation to the energy invested in the full life cycle of these resources. Therefore, the ecological footprint calculation is often complemented with the analysis of resource flows, which also includes information about the consumption and flows of mineral resources.

12.5.2. Contemporary society's ecological footprint

The area of productive land available to the human population of our planet is only 2.1 hectares per person. However, the annual average ecological footprint per person worldwide is 2.7 hectares, and this means that our planet's ecoproductivity is being consumed faster than it can regenerate. We live in nature's debt.

Industrially developed countries with a comparatively smaller number of population are responsible for most of these pressures because the average ecological footprint in the high income countries is 6.4 ha_g/per capita, while in the developing countries it amounts on average to 2.2 ha_g/per capita, which is just slightly more than the globally available amount (2.1 ha_g/per capita). In the developing countries (approximately 2.4 billion inhabitants) the ecological footprint is even smaller – only 1.0 ha_g/per capita. Such differences in the ecological footprint distribution can also be observed at the regional level.

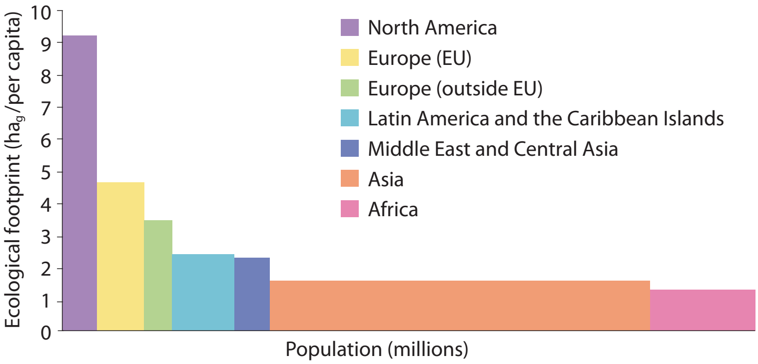


Figure 12.10. Ecological footprint in the world regions

The largest ecological footprint (9.5 ha_g/per capita) is in the United Arab Emirates and the USA (9.4 ha_g/per capita), where the consumption of non-renewable resources is the biggest. The smallest ecological footprint belongs to Afghanistan (0.48 ha_g/per capita) and Malawi (0.47 ha_g/per capita). None of the extremes is sustainable as, in the first case, more resources are consumed than available, while the second extreme is related to poverty and inability to satisfy basic human needs for food, safety and dwelling.

To satisfy all the needs of a citizen of the USA, 9.4 ha_g are required. Strikingly, if all the people of the world consumed such an amount of natural resources, we would need 5 planets. Although the average ecological footprint of the EU population is much smaller – 4.7 ha_g/per capita, it exceeds the global bioproductivity twice (2.1 ha_g/per capita) and the bioproductivity of the European Union

(2.3 ha_g/per capita) itself. This means that the territory necessary for ensuring the needs of the EU population should be twice than that available.

12.5.3. How to reduce the ecological footprint

An individual's ecological footprint can be calculated using the electronic calculator created by the World Wide Fund for Nature. By calculating one's own ecological footprint and understanding the most instrumental factors of one's impact, it is possible to trace one's habits and try changing those that most affect the environment. The three essential spheres for a decrease in the ecological footprint are food, transport and dwelling. Therefore, by choosing the local biological and seasonal food, by going on foot or using public transport or bicycle instead of a private car wherever possible, by taking care of the heat insulation of one's home as well as by using only energy efficient electric appliances, every person can decrease his or her ecological footprint in a comparatively simple way. However, all responsibility cannot be laid at the citizens' door only. Governments should also take action:

- by taking stock of nature's capital and regulating its use. A good example is the establishing of fishing quotas to ensure the regenerating capacity of fish populations;
- by including the full life cycle of goods and services associated with nature degradation and environmental pollution in the costs. One way to achieve this could be a tax reform, imposing a higher tax on the use of natural resources, at the same time alleviating the citizens' income tax. In this way, consumption would be shifted towards more environment-friendly groups of goods while preserving equilibrium in the state budget. Another option could be the eradication of subsidies that facilitate the overuse of natural resources and pollution;
- by promoting the development of environmental technologies that facilitate a more efficient use of natural resources – alleviating taxes for the enterprises that introduce environment-friendly technologies;
- by working out state procurement mechanisms that would require state institutions to choose more environment-friendly goods, thus setting an example to the private sector and creating a new type of market relations;
- by heightening public awareness of environmental issues, improving environmental education and providing citizens with the information that would enhance public understanding of environmental processes.

Since environmental problems are of global nature, they cannot be solved at the level of individual countries. This is why it is necessary to improve international environmental legislation and work out such international trade agreements that would facilitate full payment of ecological and social costs. All the above measures would ensure long-term economic stability, preservation of natural capital, higher employment level and welfare.

References

Baker S. (2006) Sustainable Development. London: Routledge.

Blewitt J. (2008) Understanding Sustainable Development. London: Earthscan.

Chambers N., Simmons C., Wackernagel M. (2000) Sharing Nature's Interest: Ecological Footprints as an Indicator of Sustainability. London: Earthscan.

Dicken P. (2008) Global Shift. Los Angeles: Sage.

Dresner S. (2008) The Principles of Sustainability. London: Earthscan.

Meadows D., Randers J., Meadows D. (2008) Limits to Growth: The 30-year Update. London: Earthscan.

Meadows D. H., Meadows D. L., Randers J. (1992) Beyond the Limits: Confronting Global Collapse, Envisioning a Sustainable Future. London: Earthscan.

OECD. (2002) Towards Sustainable Household Consumption. Paris.

United Nations Report of the World Summit on Sustainable Development. (2002) Johannesburg, South Africa, 26 August – 4 September 2002. New York: United Nations.

Wackernagel M., Rees W. (1996) Our Ecological Footprint: Reducing Human Impact on the Earth. Gabriola Island, BC: New Society Publishers.

WCED – World Commission on Environment and Development (1987) Our Common Future (The Bruntland Report). Oxford: World Commission on Environment and Development, Oxford University Press.

EEA. (2005) Household Consumption and the Environment. Accessible: *http://reports.eea.europa.eu/eea_report_2005_11/en.*

Eurobarometer. (2009) Flash EB No. 256 – Sustainable Consumption and Production. Accessible: *http://ec.europa.eu/environment/eussd/pdf/FL256_analytical%20report_final.pdf.*

Global Footprint Network. Accessible: *www.footprintnetwork.org.*

ICLEI – International Council for Local Environmental Initiatives. (2004) Aalborg Commitments. Accessible: *www.aalborgplus10.dk/.*

Sustainable Development Strategy. Accessible: *http://ec.europa.eu/comm/sustainable/.*

WWF – World Wildlife Fund. (2002) Living Planet Report 2002. Accessible: *http://globalis.gvu.unu.edu/indicator.cfm?Country=LV&IndicatorID=99.*

From the glaciers to Aral Sea. Water Unites. Accessible: *http://www.waterunites-ca.org/.*

Sustainable development goals. Accessible: *http://sustainabledevelopment.un.org/index.php?menu=1300.*

The United Nations Office for Sustainable Development (UNOSD). Accessible: *http://www.unosd.org/.*

Māris Kļaviņš, Azamat Azizov, Jānis Zaļoksnis
ENVIRONMENT, POLLUTION, DEVELOPMENT:
THE CASE OF UZBEKISTAN

University of Latvia Press
5 Baznīcas street, Riga, LV-1010, Latvia