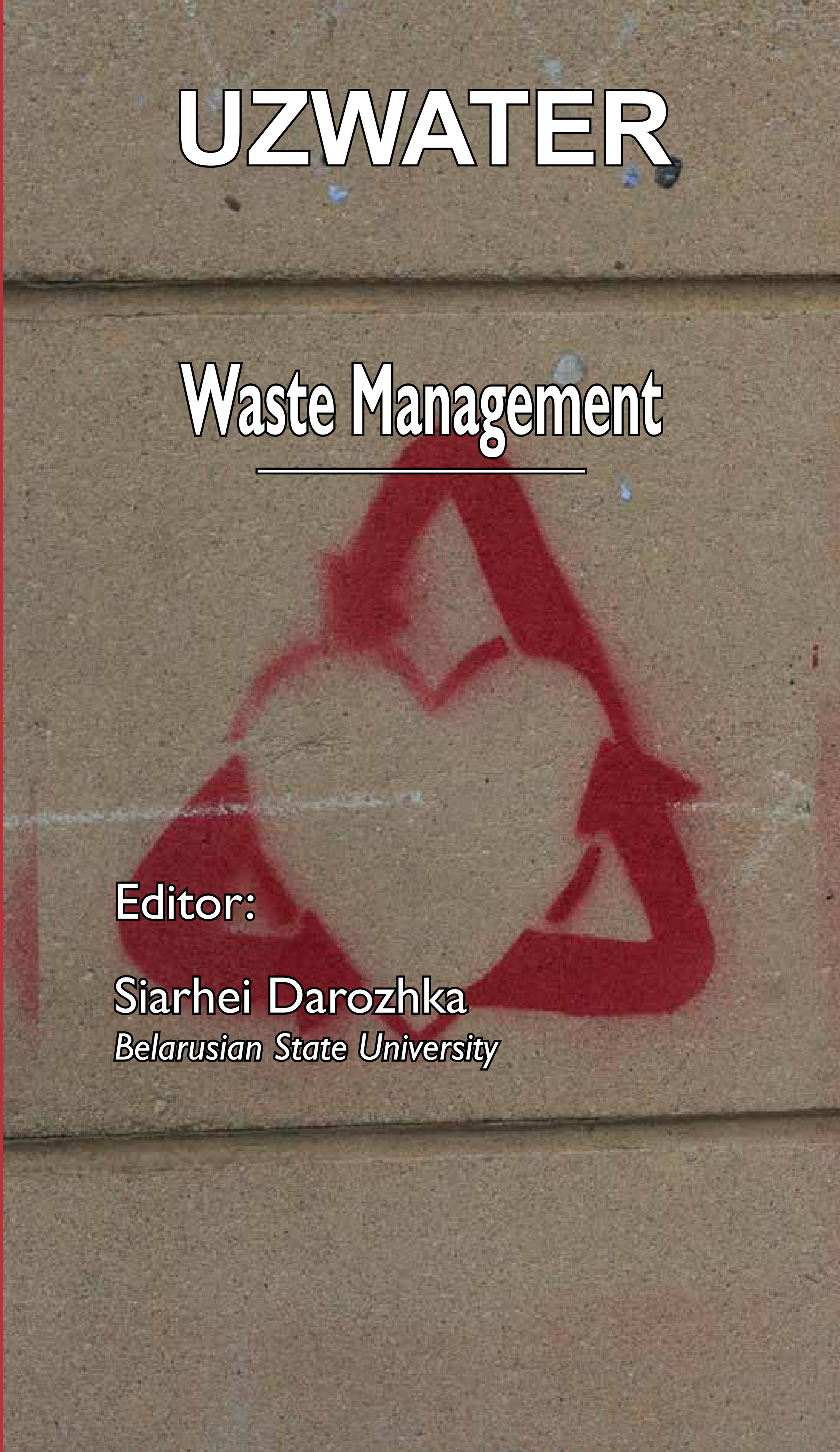

UZWATER

Waste Management

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Content Overview

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Content

Chapter 1
Origin of Waste

1.1 Waste as a problem and a resource. Generation, sources and types of waste in agriculture, industry and municipalities. Statistics and analyses.

The concept of sustainable development proclaimed by international community at 1992 Earth Summit in Rio de Janeiro expresses a rather simple idea, the essence of which is the need to achieve such a state of interaction between society, man and nature, in which they would be in harmony.

An important component of sustainable development strategy is solving waste management problem. The generation rate of municipal solid waste has been steadily increasing practically in all countries, partly because of the population growth, but mostly due to the change of life style. The average increase in waste generation amounts to 1,2-1,8% per year.

The relative volume of municipal solid waste generation varies significantly for different countries. Thus, MSW generation volume per capita varies from 700 kg (USA) to 300-400 kg (European Union countries) and ~260 kg (Eastern Europe). In urban districts waste generation increase amounts to 4-6%, which is three times faster than the population growth rate.

The first-priority tasks of the waste management system nowadays are the following:

- Reduction of waste generation
- Reduction of hazardous substances contained in waste
- Achieving the highest possible recycling and reuse rates; recycling and composting of waste components
- Environmentally friendly recycling with heat recovery (for thermal neutralization of waste)
- Environmentally-friendly disposal (landfilling) of waste remained after treatment

Since the human productive activity is, in the long run, connected with satisfying man's needs, all waste can be divided by its origin into two big categories: *production waste* and *consumer waste*.

Production wastes are including products that are nor created on purpose, but appear as by-products of the manufacture of final goods. Each production type is characterized by its own technological waste.

Industrial waste is waste material generated by an industrial activity and fully or partly devoid of their properties. Industrial waste can be liquid ок solid. Solid industrial waste include metals and alloys, wood, plastic, dust, polyurethane foam, cellular polystyrene, polyethylene and other garbage. Liquid industrial waste includes waste waters with different degree of pollution and their sludge.

Agricultural waste is any waste resulting from the agricultural activity: manure, rotten or unusable straw, hay, silage remains, spoiled or unusable compound feed and feeding slop.

Industrial and agricultural wastes are usually called wastes of production or production wastes. Some of them can have destructive or toxic impact on human or animal life and are classified as toxic wastes.

Construction waste is generated by the production of building and finishing materials (paint-and-lacquer materials, heat insulators, etc.), the construction of buildings and structures, and during erection, finishing, face works and repair operations. Construction wastes (both solid and liquid) include expired, unusable, defective, excessive, broken or rejected products and materials: metal sections, metal and nylon pipes, gypsum plasterboard sheets, fibre reinforced gypsum panels, cement-shaving plates, etc.

Plastic production waste is hazardous in its own way. They do not decompose for quite a long period. Plastic materials can remain unaffected in the ground for tens or even hundreds of years. Million tons of polyethylene is spent to produce disposable package to be thrown away.

Some specific production processes and processes involving radioactive substances (at radiochemical plants, nuclear power plants, research-and-development centres) generate *radioactive waste*. This waste is characterized by an increased negative impact on the human health and the environment. The principal aim of treating low-, intermediate- and high-level radioactive waste is its neutralization prior to safe disposal and landfilling. In some cases radioactive waste can be treated to recover radioactive elements. Radioactive waste can be liquid (and usually are) or solid. This category of waste not only poses a serious environmental problem, but can also lead to an ecological catastrophe.

Consumer wastes are including expired household appliances and products, as well as unwanted products or their remains and are generated in the municipal system.

The most widespread consumer waste are the following:

- municipal solid waste (MSW), produced in residential and uninhabited sectors;
- bulky materials – expired household appliances and furniture (refrigerators, washing machines, gas cookers, sofas etc.);
- automobile scrap – expired cars;
- bulky waste of rubber products (e.g. tyres, including tyres with metal cords);
- used accumulators;
- used mercury bulbs;
- electronic appliances scrap (expired radio and TV equipment, etc.)

By the morphological composition MSW are categorized according to their components: paper and cardboard; food waste; wood; metal (ferrous and non-ferrous); textile; bones; glass; leather; rubber; polymeric materials; others (unclassified waste); chaff (particles smaller than 15 mm). The data on the morphological composition of MSW in different climatic zones is important for designing waste management facilities (table 1.1).

The table does not contain data on bulky waste (old furniture, refrigerators, washing machines, cut trees, large-sized packaging), i.e. MSW which is not discharged into standard containers (0.75 m^3) and are collected separately.

Table 1.1 The morphological composition of Municipal Solid Waste in different climatic zones, масс. %

Component	Climatic zone		
	central	southern	northern
The morphological composition of MSW			
Food waste	35-45	40-49	32-39
Paper, cardboard	32-35	22-30	26-35
Wood	1-2	1-2	2-5
Ferrous metals	3-4	2-3	3-4
Non-ferrous metals	0,5-1,5	0,5-1,5	0,5-1,5
Textile	3-5	3-5	4-6
Bones	1-2	1-2	1-2
Leather, rubber	0,5-1	1	2-3
Glass	2-3	2-3	4-6
Stones, plaster	0,5-1	1	1-3
Plastic	3-4	3-6	3-4
Other	1-2	3-4	1-2
Chaff (smaller than 15 mm)	5-7	6-8	4-6

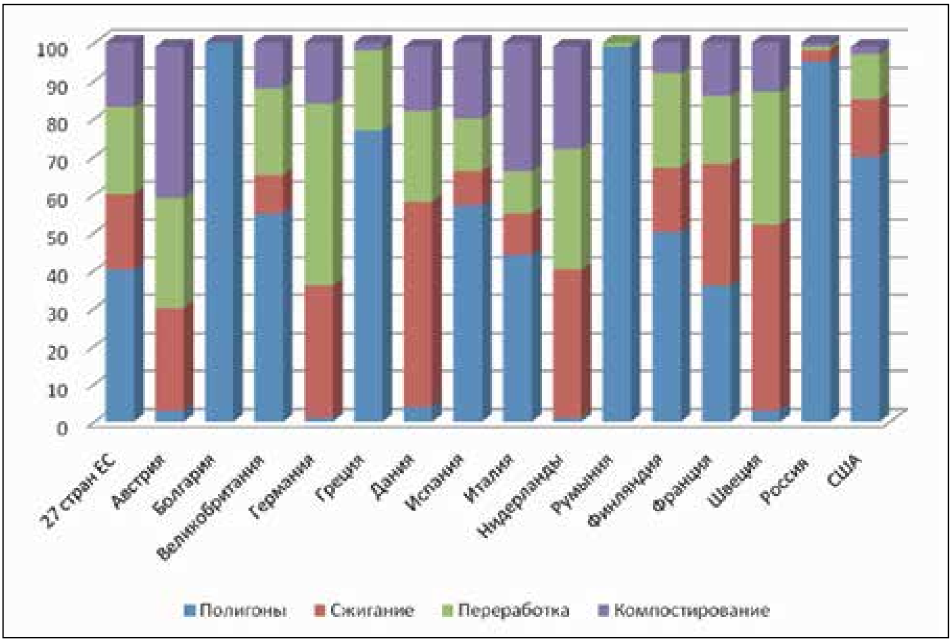

Figure 1.1 MSW management methods in different countries, % (Municipal Waste, 2010)

However, the composition and quantity of MSW can vary depending on a range of reasons. Experience shows that with the course of time, if separate collection is not organized, MSW tend to contain more paper and polymeric materials. The quantity of food waste and empty bottles can vary, too. Seasonal variations in MSW composition are characterized by increasing the proportion of food waste from 20-25% in spring to 40-55% in autumn, which is explained by higher consumption of vegetables and fruit (especially in southern urban districts). In autumn and winter the proportion of small chaff (street sweepings) decreases from 20 to 7% in the southern zone and from 11 to 5% in the central zone.

The bulk of MSW is landfilled. According to the Eurostat data, the average rate of landfilling MSW for 27 EU countries is 40%, for incineration – 20%, recycling – 23% and composting – 17%. But as can be seen from figure 1.1, the relative proportions of different waste management methods vary significantly for different countries and are undoubtedly dependent on the countries' economic development. Thus, while the proportion of landfilling MSW in Germany is 1%, in Austria – 3%, in Bulgaria and Romania it is almost 100%. The USA landfill 70% of MSW, and Russia – more than 90%.

Some estimates claim that only 10% of annually generated waste is processed (incinerated, composted or separated) at the global level.

Based on their aggregate state, all wastes can be divided into *solid, liquid and gaseous*. Solid and liquid forms are typical for all groups of waste, while gaseous waste are mainly industrially produced (including automobile exhausts).

If waste contains certain chemical substances in a specified concentration, it is classified as hazardous. But any classification of waste is relative and can change in the course of time. Thus, for example, industrial wastes used to be treated as hazardous if they contained any of the eight heavy metals, four insecticides or two herbicides. According to the new classification, this list now includes twenty five other organic substances, which resulted in the increase of industrial waste regarded as hazardous

The prior target in managing solid waste is the so-called multi-ton waste, since it is the main source of environmental pollution, but at the same time, if involved in production, can provide maximum benefits.

Multi-ton *inorganic non-metallic mining waste* is usually employed for filling worked-out areas and as a feedstock for the production of building materials and in road construction. Such a multi-ton waste as phosphogypsum is generally used for producing astringents for construction mixtures and building materials (instead of mineral resources), and also as ameliorators for soils. Glass scrap and ceramics making the bulk of this waste category can be used for the production of building materials and reused for manufacturing analogous products.

Organic waste is characterized by the possibility to be processed and eliminated by means of thermal processes both separately or in combination with other processes (at the final stages of thermal treatment).

At the same time organic waste can be used for its intended purpose (often at source) as a for the main production: waste paper – for the production of paper and cardboard; wood – for the manufacture of furniture and building materials; wasted leather – for leather dressing; plastic – for the production of plastic goods; rubber – for the manufacture of rubber goods; textile waste can be reused in textile industry, etc. An important method of organic waste treatment is its recovery for energy (incineration with heat recovery, anaerobic digestion for biogas production, etc.). The specificity of food and plant waste determines its utilization for the production of new goods (compost, biofuel, fodder, alcohol, etc.).

Mixed wastes are difficult to process and utilize. Most mixed wastes contain metals and are frequently treated to recover them. If mixed waste contains organic substances, it is potentially possible to use thermal methods for their processing (incineration, pyrolysis). Being multi-component, mixed wastes require combined processing including sorting and complex utilization methods.

Waste generation results in an irretrievable loss of an enormous quantity of organic and mineral substances from the biological cycle. While choosing waste treatment methods it is necessary to consider not only the treatment costs, the environmental loading of the chosen methods and the economic benefits of recycling, but also the possibility and practicability of returning mineral and organic substances to the biological cycle.

Using waste as a resource allows to utilize natural resources more efficiently and reduce harmful air emissions and waste water generation. For example, by using waste paper for paper production it is possible to reduce harmful air emissions by 70-89%, water pollution by 30-35% as compared with the use of natural raw materials. Approximately 4 m^3 of wood can be saved by using 1 ton of waste paper. Thus, we can save thousands of hectares of forests that in its turn purify the air from carbon dioxide.

There is an innovation technique aimed at producing diesel fuel and petrol from plastic waste. This technique developed by Japanese scientists makes it possible to get up to 5 litres of diesel fuel or petrol from 10 kg of plastic waste. Such methods are not only economically beneficial, but also help to reduce the anthropogenic load on the environment.

In some countries hundreds of thousands of used batteries are discharged to municipal landfills. Together with industrial and municipal waste, hundreds of tons of aluminium cans, mercury- and tin-containing appliances, and tungsten filament lamps are landfilled in many countries. It is much more profitable to process waste to get secondary raw materials than to use natural resources for the same manufacturing purposes. Extracting metals from their ores is 25 times more expensive than collecting and processing analogous non-ferrous metal waste.

Glass tare is a valuable resource, too. Unfortunately, in most countries of Eastern Europe used glass tare is, at best, landfilled. Although reusing glass tare is more profitable than producing the new one, this approach is often not realized properly.

The development of the automobile industry resulted in a greater negative impact on the environment. Apart from accumulators, plastic and metals, automobiles are a source of an enormous quantity of wasted rubber tyres. The main problem with this waste is that nature cannot decompose rubber. It is possible to avoid littering the environment with rubber tyres by processing them into rubber grains sized 5 mm. These grains can be further utilized to produce different goods.

Waste is one of the main environmental problems nowadays, which is potentially hazardous to the human health and the environment. In many countries there is still misunderstanding as to the gravity of the situation associated with solid municipal wastes, and therefore they do not have stringent regulations and sufficient and feasible legal normative acts, concerning waste management issues.

Chapter 2
Definitions and Classifications of Waste

2.1 Definition of waste

There are many types of waste that are generally classified by their source into agricultural, industrial and household / municipal wastes.

Classifying generated waste will help:

- decide how to handle particular type of waste;
- complete the paperwork that must be provided to waste contractors so that they can manage waste - this is a part of the so called "duty of care":
  - classify waste and indicate if it's hazardous or non-hazardous so that you can deal with it correctly;
  - register the premises if organization produces or stores hazardous waste;
  - usually get a permit to store, treat, transport or dispose of waste, as required by the local legislation;
  - store waste safely and securely;
  - follow the rules for waste transportation for moving it off from your business site;
  - check that any business you use to deal with waste is licensed, and keep proof of this – e.g. take a copy of their license.

European Directive 2008/98/EC (Waste Framework Directive - WFD) sets the basic concepts and definitions related to waste management, such as definitions of waste, recycling, recovery. It explains when waste ceases to be waste and becomes a secondary raw material (so called end-of-waste criteria), and how to distinguish between waste and by-products. The Directive lays down some basic waste management principles: it requires that waste be managed without endangering human health and harming the environment, and in particular without risk to water, air, soil, plants or animals, without causing a nuisance through noise or odors', and without adversely affecting the countryside or places of special interest.

WFD defines "waste" as "any substance or object which the holder discards or intends or is required to discard".

Table 2.1 Waste categories as defined in the EU Directive 75/442/EEC

Category	Description
Q1	Production or consumption residues not otherwise specified below
Q2	Off-specification products
Q3	Products whose date for appropriate use has expired
Q4	Materials spilled, lost or having undergone other mishap, including any materials, equipment, etc., contaminated as a result of the mishap
Q5	Materials contaminated or soiled as a result of planned actions (e.g. residues from cleaning operations, packing materials, containers, etc.)
Q6	Unusable parts (e.g. reject batteries, exhausted catalysts, etc.)
Q7	Substances which no longer perform satisfactorily (e.g. contaminated acids, contaminated solvents, exhausted tempering salts, etc.)
Q8	Residues of industrial processes (e.g. slags, still bottoms, etc.)
Q9	Residues from pollution abatement processes (e.g. scrubber sludge's, baghouse dusts, spent filters, etc.)
Q10	Machining/finishing residues (e.g. lathe turnings, mill scales, etc.)
Q11	Residues from raw materials extraction and processing (e.g. mining residues, oil field slops, etc.)
Q12	Adulterated materials (e.g. oils contaminated with PCBs, etc.)
Q13	Any materials, substances or products the use of which has been banned by law
Q14	Products for which the holder has no further use (e.g. agricultural, household, office, commercial and shop discards, etc.)
Q15	Contaminated materials, substances or products resulting from remedial action with respect to land
Q16	Any materials, substances or products which are not contained in the abovementioned categories.

This definition leaves out waste fractions collected separately at the source of their generation (e.g., paper, glass, plastic, metals). Besides, some other types of waste are disregarded, such as construction waste.

It is rather difficult to differentiate solid municipal wastes by their source of generation. For example, waste generated by housekeeping operations (and similar to that in composition) could be named household waste. However, it is actually often mixed and collected together with similar waste from other sources, like offices, restaurants, etc.

Solid municipal waste is usually composed of paper, cardboard, plastic, glass, metals, food residue, garden waste, textile and other similar wastes. Waste produced by repair works, construction of various buildings, structures and roads is generally not included into SMW, but regarded as production waste. Similar waste generated during household construction and repair works should also be regarded as a separate flow of bulky waste, although in practice it is often collected with SMW.

Table 2.2 An example of wastes classification by the source of their generation

Type of waste	Source of generation
Agricultural waste	Wastes from agricultural works, especially from livestock farming
Wastes resulting from exploration, mining and quarrying	Wastes from mineral resource industry, mainly consisting of inert mineral materials
Wastes resulting from soil excavation	Organic and mineral materials resulting from soil excavation
Construction waste	Wastes resulting from construction, reconstruction and demolition of buildings, consisting mainly of inert materials and wood
Waste generated by industrial/ energy sector	Production waste, sometimes including waste from energy sector (e.g., flue ash)
Sewage sludge	Solid organic waste mainly resulting from wastewater treatment
Hazardous waste	Solid waste, containing compounds that are harmful and hazardous to human health and the environment
Production waste similar to SMW	Wastes generated by offices, shops, restaurants, hotels, etc., that are similar to SMW in composition
SMW	Wastes resulting from housekeeping operations and / or similar waste from commercial and industrial organizations, as well as waste collected and managed by local municipalities and authorities.

The wording used in the European Union legislation lets every country have its own definition of waste. Therefore, in some countries SMW includes only waste generated by households.

In the Republic Uzbekistan Law «About waste» (2002) the similar definition of "waste" is applied: «… it is the rests of raw materials, materials, half-finished products, other products or products which were formed in the manufacturing processes or consumption, and also the goods (production) which has lost the consumer properties».

2.2 Waste classification

In the European Union the following categories of waste are defined in the Directive 75/442/EEC (Appendix I) with amendments, stated in the Directive 91/156/EEC:

Optional classification of waste can be based on that given in tables 2.2 and 2.3. It should be noted that some waste flows, despite having similar composition, must be classified separately by the sources of their generation. For example, food residue and organic garden waste can be regarded together as a separate flow of biodegradable waste, while wood waste, although biodegradable too, should be regarded separately due to their usability for incineration (high calorific value), shorter decomposition period and presence of chemical additives (e.g., lacquers and dyes).

Table 2.3 The principle of waste classification by main material

Main fraction	Sub-fraction	Components	Examples
Organic components	Food residue	Biodegradable household food residue, as well as food residue from restaurants, cafes, canteens	Brad, ground coffee, cooked or raw foodstuff, food residue, fruit and vegetables, meat, fish, etc.
	Garden waste	Biodegradable waste from household and city parks, gardens, etc.	Flowers, weed, mown grass, cuttings of hedge, leaves, branches, etc.
	Biodegradable waste	Other biodegradable waste not mentioned above	Remains of animals, bones, excrements, etc.
Wood	Unprocessed wood waste	Wooden objects without chemical additives or decorative coats	Unprocessed hard timber and scrap, bottle corks, cork packaging, pallets, etc.
	Processed wood waste	Wooden objects, coated with dyes, lacquers, hardeners, etc.	Processed compacted wooden plates (e.g. particle board, veneer, furniture), hard timber (e.g., construction materials, fences, furniture)
Paper and cardboard	Glazed paper, cardboard and wallpaper	Non-degradable paper	Glazed brochures, magazines, promotional materials, photographic paper, wallpapers, etc.
	paper and cardboard packaging	Unglazed packaging	Packages, cardboard crates, , corrugated board, paper bags, wrapping paper, waxed cardboard and paper
	Newspapers	Newsprint	Newspapers, promotional materials, etc.
	Other paper or cardboard waste not used for packaging	Other paper waste not mentioned above	Books, envelopes, files, folders, office paper, telephone directories, tissues, toilet paper
Plastic	Wrapping film	All types of plastic wrapping film	Shopping bags, wrapping film, plastic food containers, etc.
	Non-wrapping film	Various types of non-wrapping plastic film	Non-wrapping film, polyethylene bags
	Packaging – high pressure plastic	Transparent and coloured plastic	Various plastic bottles, jars, flasks, etc.
	Other types of packaging – high pressure plastic	Transparent and coloured plastic packaging, except bottles and flasks (containers)	E.g., packaging from household appliances, food packaging, pipes, tanks, vessels, lids (e.g., for margarine, ice-cream containers), bottle corks, etc.
	High pressure plastic not used for packaging	All high pressure plastic objects not used for packaging	Cosmetic/ glue applicators, paint brushes, CDs, records, cassettes, linoleum, floor tiles, garden tools, hoses and flower pots, pens, toys, toilet lids, pipes (pumps), etc.
Glass	Transparent glass packaging	Bottles and jars made from transparent glass	Food bottles and cans (e.g., from beer, cider, milk, water, wine, baby foods, coffee, jams, pickles, sauces), medicine flasks
	Coloured glass packaging	Bottles and jars made from coloured glass	
	Other types of glass packaging	Bottles and jars made from other types of coloured glass	Kitchenware, flat glass (e.g., table cover, window glasses, mirrors, armoured windscreens). Bulbs (usual and fluorescent), TV and computer monitors are usually excluded from this category.
	Different glass objects not used for packaging	Glass objects not used for packaging	

Table 2.3 The principle of waste classification by main material (forts.)

Main fraction	Sub-fraction	Components	Examples
Textile	Clothing textile	Natural and artificial clothing textile, except footwear	Clothing textile made from natural, synthetic or combined materials, except footwear
	Non-clothing textile	Natural and artificial textile and bedclothes, except footwear and clothes	Textile not used as clothing, e.g., blankets, carpets, fabrics, cords, curtains, upholstery, floor mats, linen, cushions, ropes, mats, towels, etc.
Metals	Ferrous packaging	Ferrous packaging for food and drinks, as well as non-food cans and containers	Food containers, beverages cans, aerosols (deodorants, perfumes, hairsprays), etc.
	Non-ferrous packaging	Non-ferrous cans, containers and other types of packaging	Cosmetic/ glue applicators, paint brushes, CDs, records, cassettes, linoleum, floor tiles, garden tools, hoses and flower pots, pens, toys, toilet lids, pipes (pumps), etc.
	Various ferrous or non-ferrous objects not used for packaging	Other bulky ferrous objects, except those for storing food	Construction materials, radiators, vehicle spares, tableware, keys, tools
Hazardous household waste	Batteries and accumulators	Various types of household and automobile batteries, including rechargeable and non-rechargeable	Lead acid batteries, nickel cadmium batteries and other household batteries and accumulators (including rechargeable and non-rechargeable)
	Various hazardous waste	Other potentially hazardous types of waste	Asbestos, cooking oils, fire extinguishers, household and garden chemicals, glues and dissolvent's, drugs, denatured alcohol, mineral, synthetic and non-food organic oils and fats and their filters, dyes, photochemical cells, coolants, white spirits
Combined	Complex packaging	Any complex/ combined packaging that is difficult to disjoint into components	Aluminium, foiled drinks packaging, e.g. packaging for milk, fruit juice, etc.
	Complex non-packaging waste	Any complex/ combined non-packaging waste that is difficult to disjoint into components	Components of household appliances, car parts, machine details, footwear
	Mixed electric and electronic waste	Bulky household appliances	Air conditioners, controllers and thermostats, ovens, refrigerators and freezers, dishwashers, washing machines, etc.
		Small household appliances, lighting equipment, toys, controlling and monitoring instruments	Saws, scales, sewing machines, razors smoke detectors; toasters; vacuum-cleaners massagers, irons, etc
		IT and telecommunication equipment	IT equipment (personal computers and peripherals), data communications equipment, remote control consoles for videogames, audio and video equipment, etc.

Table 2.3 The principle of waste classification by main material (forts.)

Main fraction	Sub-fraction	Components	Examples
Inert waste	Soil and stones		Boulders, bricks, gravel, pebbles, sand, soil, stones
	Various inert materials	Any inert materials except soil and stones	Ceramic and clay flower pots
			Ceramic/ earthenware, pottery, ceramic/ stone floor and wall tiles, vases
Other categories	Diapers	Disposable diapers	Diapers, laminated/ non-laminated paper
	Medicinal/ biological waste	Household and medicinal waste	Bandaging materials, binders, implants, syringes, etc.
	Various categories	Any other material difficult to classify under any ither category	
Fine-dispersed waste	10 mm fractions		Ash
			Sand
			Small fragments (<10 mm) of all the above mentioned categories

Production waste is remains of raw materials, materials and semi-finished products resulting from production processes and services, that have partially or completely lost their properties and do not comply with standards. Whether pretreated or not, these remains can be used in production or consumption spheres, specifically, for making by-products.

By-products are derived from physical and chemical processing of raw materials together with the primary product, but the former are not the aim of production. In most cases they are tradeable, they must comply with specific standards, technical requirements, and their production is planned.

Production waste results from imperfect technological processes, mostly from inadequate work organization and imperfect economic mechanism. Here belong:

- Waste generated during mechanical and physical and chemical processing of feedstock and materials;
- Waste resulting from minerals extraction and dressing;
- Substances captured while treating exhaust technological gases and waste water.

Consumption waste is various used products and substances that are not economical to recover. For example, rundown or obsolescent machines, capitalized products (industrial waste) and unfit or outdated home appliances and personal belongings (domestic consumption wastes).

Production waste (technogenic waste) and consumption waste (anthropogenic waste) that can be used as a feedstock for manufacturing useful products are called *secondary raw materials.*

The wide assortment of wastes generated by various industrial enterprises hinders their classification, record keeping, collection and recycling.

Due to many reasons, there is currently no common comprehensive scientific classification of solid industrial wastes. The existing classifications of solid wastes are very multiform and one-sided.

Various approaches to waste classification are based on the following classifying criteria:

- source of generation (industrial sector);
- stage of production cycle; type of waste;
- harmfulness to the environment and human health;
- direction for utilization;
- efficiency of utilization;
- amount of stock and generation;
- knowledge and development of recycling technologies.

Thus, solid wastes are classified by industrial sectors (chemical, metallurgical, electro technical wastes and others) and by types of manufacture (wastes resulting from sulfuric acid refining, car assembly, bearing production, etc.).

All solid industrial wastes can be divided into two types: non-toxic and toxic. The majority of solid industrial wastes are non-toxic. The examples of toxic waste are sludge from galvanizing plants and pickling baths.

Wastes can also be classified into metallic, non-metallic and mixed. Non-metallic wastes are sub-divided into chemically inert (earth deposits, ash, etc.) and chemically active (rubber, plastic, etc.). Mixed waste includes all sorts of industrial and construction rubbish.

Classification of wastes by their harmfulness to the environment and human health is widely used, too. Thus, in the European Union there are 14 hazard classes of waste: 1 – explosive waste; 2 – oxidizing waste; 3(A) – highly flammable; 3 (B) – flammable; 4 – irritant; 5 – harmful; 6 – toxic; 7 – carcinogenic; 8 – corrosive; 9 – infectious; 10 – teratogenic; 11 – mutagenic; 12 – substances which release toxic gases in contact with water; 13 – waste emitting harmful substances; 14 – ecotoxic.

Most former Soviet Union countries, the Republic Uzbekistan as well, apply a bit different classification of hazardous industrial waste. According to this classification, there are 4 hazard classes of waste: 1 – extremely hazardous; 2 – highly hazardous; 3 – moderately hazardous; 4 – low-hazard.

Wastes containing, for example, such metals and compounds as mercury, potassium chromate, tricolor-antimony, arsenic oxide and other highly toxic substances, must be regarded as hazard class I. Wastes containing cuprous chloride, nickel chloride, antimony trioxide, lead nitrate and others belong to hazard class II. Wastes containing copper sulfate, lead monoxide, copper oxaloacetate, carbon tetrachloride must be regarded as hazard class III. The hazard class of waste is calculated by a specific method approved, as a rule, by national Ministries of Health.

The European Union implemented a classification based not only on the type of waste, but also its origin, how it was collected and which authority is in charge of it. Here we are interested in type-based classification. Classifying waste depends on what kind of waste it is and its impact on humans or the environment. We, therefore, distinguish between:

- Hazardous waste which contains varying quantities of toxic or hazardous elements that may have an impact on human health and the environment. It may be organic (solvents, hydrocarbons, etc.), mineral (acids, metal hydroxide sludge, etc.) or gaseous. Hazardous waste can be classified into three subcategories: *Special Industrial Waste* (SIW), *Special Household Waste* (SHW) and *Medical Waste* (MW). According to Eurostat, the volume of hazardous waste produced stood at 94.5 million tons in the European Union in 2010, or less than 4% of all waste produced.
- Non-hazardous waste. Some of this waste is *recyclable* (wood, household packaging, ferrous metals, plastics, glass, paper, etc.), while others are *compostable or biodegradable* (bio waste, green waste, etc.). It may also refer to waste treatment by-products. Non-hazardous waste represents approximately 1/3 of the waste produced in the European Union.
- Inert waste, waste that does not decompose, does not burn and produces no other physical or chemical reaction with the environment. It is not biodegradable and poses no danger to humans or the environment (e.g., backfill or rubble). Inert waste is derived from extractive industries and the building and public works sector. Mineral materials (stone, marble, sandstone, slate, etc.), concrete, bricks, glass, and even soil are included. In 2010, the construction sector generated 855 million tons of waste in the European Union. Extractive industries in turn, produce 727 million tons of waste. Inert waste in our estimation, therefore, accounts for approximately 60% of all waste produced in the European Union.

This official classification has enabled governments to steer and evaluate waste management policies. Lastly, it allows those involved in waste management

Figure 2.1. Production of different types of waste in the European Union (Source: Eurostat, 2010).

(businesses, local authorities, organisations, etc.) to have common benchmarks to facilitate understanding and discussion.

Chapter 3
Environmental Impacts and Health Risks

3.1 Environmental impacts and health risks associated with waste management

Uncontrolled waste streams produce an adverse impact on the environment and human health (the influence of toxic substances on human health, higher risks of fires, general insanitation, etc.). Toxic substances (e.g. heavy metals, persistent organic compounds and dioxins) while being inhaled or while penetrating into the human organism or just contacting it, can produce a strong adverse impact on human health or even cause death. Besides, they can cause pollution of water-supply systems.

Waste collection includes transporting which results in emissions of carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NO_x), suspended particles (SP), lead (Pb) and volatile organic compounds (VOCs). These substances produce an adverse impact on the environment and human health.

Landfilling of MSW requires allotment of land sites for the construction of landfills and results in air, water and soil pollution due to air emissions of carbon dioxide (CO_2) and methane (CH_4), and leakage of chemicals and pesticides into the soil and underground water. Landfill gas created by the decomposition of wastes, is highly explosive when accumulated in a restricted space. Many decommissioned, inadequately designed or operated SMW landfills are a source of toxic emissions, that provoke a burst of such illnesses as leukemia, gallbladder, liver, prostate and breast cancers.

Hazardous fractions (e.g. crashed glass, razors, syringes and other medical wastes, aerosol cans and chemicals) can cause cuts and intoxications, especially to people doing waste sorting.

Landfilled chemicals react with each other, which results in release of liquid and gaseous hazardous substances that can produce a strong adverse impact on human health and the environment or sometimes even cause death.

The operation of waste incinerators causes air emissions of dioxins and acid gases, such as nitrogen oxides (NO_x), sulphur dioxide (SO_2), hydrochloric acid (HCl), that adversely impact both the environment and human health. Apart from the mentioned gases, air emissions can contain a lot of other contaminants in various proportions, such as highly toxic furans, cadmium, mercury, lead and other volatile compounds of hazardous metals, benzene, toluene, polychlorbiphenyl, alkalis, alkens and other organic compounds. These emissions are able to produce negative impacts on human health, including congenital defects, asthma, respiratory illnesses and various cancers.

Waste composting has a negative impact on human health, too. People living in the vicinity of composting facilities tend to be prone to respiratory illnesses.

The forms of the above mentioned adverse impacts produced by different waste management methods depend a lot on local conditions. Table 3.1 presents the effects produced by different stages of waste management on the environment and human health.

3.2 Toxicity and health effect

An individual might be exposed to a particular substance by one or more routes – for example, by breathing in air containing the substance; by consuming food or drink containing the substance; or by contact of the substance on the skin. Any substance to which we are exposed has the potential to cause harmful effects. The harm that might be caused by exposure to a particular substance is determined by the dose – that is, the amount of substance experienced by an individual. In general, the higher the dose, the higher the risk of adverse effects, and the more severe any effects would be expected to be.

This means that at a high enough doses, even an innocuous substance such as water can be lethal. Conversely, at low enough doses, no substance will be toxic (with the exception of a few cancer-causing chemicals, and even for these substances, exposure at very low concentrations will have a vanishingly small likelihood of any significant effect on health). Even substances that are essential to our bodies, such as iron, can be toxic at high doses.

Health effects associated with mortality (mainly from cardiovascular and respiratory causes), adult cancers, congenital malformations, respiratory symptoms, odour annoyance and physical injuries were assessed, and aggregated into an overall measure of the disease burden (in disease adjusted life years).

The most important heath impacts usually are observed due to occupational accidents related to the collection, loading and transport of waste. Transport of waste (often done using highly polluting trucks) is also an important (and often neglected) cause of exposure to air pollution. Impacts from landfills and incinerators are limited due to the strict legislation on emissions, but both landfills and mechanical-biological treatment plants were responsible for a considerable

Table 3.1 Sources, pathways, emissions and potential effects of waste management methods

<table>
<tr><th rowspan="2">Source Potential effects (Waste disposal method)</th><th rowspan="2">Emission(s)</th><th rowspan="2">Pathway(s)</th><th rowspan="2">Receptor(s)</th><th colspan="2">Potential effects</th></tr>
<tr><th>Human</th><th>Environmental</th></tr>
<tr><td>Landfill</td><td>Dust; odour; micro-organisms; litter; landfill gas (CH4, CO2 and numerous trace compounds); exhaust gases from combustion of landfill gas (including carbon dioxide, carbon monoxide, oxides of nitrogen, sulphur dioxide, and other trace components)</td><td>Air- emissions of materials to air directly from the landfill during tipping, compacting, covering and storage activities; emissions to air of fugitive landfill gas; emissions to air of products of landfill gas combustion.</td><td>Nearby sensitive receptors in the vicinity of the landfill site; nearby sensitive habitats</td><td rowspan="4">Potential for exposure to a variety of potentially harmful materials which have been investigated in connection with birth defects, asthma, respiratory disease and cancer Potential for exposure to harmful materials which have been investigated in connection with cancer, asthma, respiratory disease, birth defects</td><td>Potential for soil acidification due to deposition of acid gases; increases in soil metals; vegetation damage due to oxides of nitrogen (NOx) and sulphur dioxide (SO2)</td></tr>
<tr><td></td><td>Leachate containing salts, heavy metals, biodegradable and persistent organics to groundwater, surface water and sewer</td><td>Water- leaching of materials into groundwater and surface waters due to fugitive escapes of leachate; emissions of treated and untreated leachate via permitted routes</td><td>Nearby sensitive receptors, groundwater users and surface water users; nearby sensitive habitats</td><td>Potential for contamination of ground and surface water with metals, organic compounds, bioaccumulation of toxic materials</td></tr>
<tr><td></td><td>Metals (Zinc (Zn), lead (Pb), copper (Cu), arsenic (As), and various organic compounds</td><td>Land-contamination of land during postoperative phase</td><td>Nearby sensitive receptors and users of postoperative site</td><td>Potential for contamination of flora and fauna in contact with contaminated land, and possible bioaccumulation of toxic materials in flora and fauna</td></tr>
<tr><td>Thermal treatment (including incineration)</td><td>Emissions of SO2, NOx, hydrogen chloride, hydrogen fluoride, volatile organic compounds (VOCs), carbon monoxide, carbon dioxide (CO2) nitrous oxide (N2O), dioxins and furans, metals (Zn, Pb, Cu, As), dust, odour, micro-organisms</td><td>Air- emissions from waste during handling and storage operations; emissions of materials during handling of waste ash; emissions of gases and particles from combustion of waste</td><td>Nearby sensitive receptors; nearby sensitive habitats; sensitive receptors within the influence radius of the combustion gas plume; sensitive receptors exposed to ash during re-use</td><td>Potential for soil acidification due to deposition of acid gases; increases in soil metals/dioxins; vegetation damage due to NOx and SO2</td></tr>
</table>

Table 3.1 Sources, pathways, emissions and potential effects of waste management methods

Source Potential effects (Waste disposal method)	Emission(s)	Pathway(s)	Receptor(s)	Potential effects	
				Human	Environmental
	From ash: metals (including Zn, Pb, Cu, As), dioxins and furans; From deposition of combustion gases: sulphuric, carbonic and nitric acids, particulate matter, metals (including Zn, Pb, Cu, As), fluoride, chloride, dioxins and furans	Land- disposal of bottom ash and fly ash residues to land via ash reuse programs; leaching of materials from landfilled ash; deposition of combustion gases and particles to land from airborne emissions	Sensitive receptors exposed to soil contaminated with ash or deposited emissions, or to produce grown in contaminated soil;	Potential exposure to metals, dioxins and furans. Has been investigated in relation to cancer and birth defects.	No significant effects likely
Composting	Methane, carbon dioxide, dust, odour, bacteria, fungi	Air- emissions of from waste handling, compost generation and compost removal operations	Nearby sensitive receptors	Potential for exposure to harmful bacteria and fungi. Investigated in connection with respiratory and other diseases	No significant effects likely
	Trace contaminants in original compost feedstock. Might include: metals and organic compounds	Land- potential for transfer of contaminants from compost into subsequently treated soils, and potential for contamination of food chain	Sensitive receptors exposed to soil fertilised with compost and to produce grown in contaminated soil	Potential for exposure to contaminants in original feedstocks via deposition to soils when compost used on soils. Potential for uptake by produce of fertilised land	Potential for increase in contaminants in original feedstocks when compost used on soils.
Materials Recycling Facility	Dust and odour	Air- emission of materials during waste storage and sorting	Nearby sensitive receptors	Potential for dust and odour nuisance; possible ill health due to dust inhalation	No significant effects likely

Table 3.1 Sources, pathways, emissions and potential effects of waste management methods

Source Potential effects (Waste disposal method)	Emission(s)	Pathway(s)	Receptor(s)	Potential effects	
				Human	Environmental
	Non-recyclable materials from feedstock	Land - emissions arising from landfilling of final residues	Receptors in vicinity of landfill used to dispose of final residues	No significant effects likely	No significant effects likely
Transporta-tion	Vehicle emissions (including: carbon monoxide, carbon dioxide, nitrogen oxides, particulate matter, metals, rubber dust, VOCs. From accidental spillages: VOCs, dust, odour, litter	Air- emissions associated with vehicle operations; emissions from accidental spillages	General public, sensitive receptors in the vicinity of transfer stations or the final reception point	Potential for exposure to exhaust fumes along transport routes and at transfer stations.	Potential for exposure to exhaust fumes along transport routes and at transfer stations.
	Fuel derived VOCs, (diesel and petrol); surfactants and liquid wastes from cleaning	Water- potential for contamination of groundwater and surface water arising from accidental spills of waste water and during cleaning processes	Sensitive receptors in the vicinity of transfer stations or the final reception point	Potential for contamination of groundwater used as water supply, and potential contamination and subsequent exposure to surface waters	Potential for contamination of groundwater or surface waters

impact in the form of respiratory symptoms and odour annoyance. The main opportunity to reduce health impacts in the future would be through policies that encourage waste reduction, recycling, clean transport, composting and waste treatment before the final destination.

3.3 Environmental effects

Surface water contamination

Changes in the water chemistry due to surface water contamination can affect all levels of an ecosystem. It can impact the health of lower food chain organisms and, consequently, the availability of food up through the food chain. It can damage the health of wetlands and impair their ability to support healthy ecosystems, control flooding, and filter pollutants from storm water runoff. The health of animals and humans are affected when they drink or bathe in contaminated water. In addition aquatic organisms, like fish and shellfish, can accumulate and concentrate contaminants in their bodies. When other animals or humans ingest these organisms, they receive a much higher dose of contaminant than they would have if they had been directly exposed to the original contamination.

Groundwater contamination
Contaminated groundwater can adversely affect animals, plants and humans if it is removed from the ground by manmade or natural processes. Depending on the geology of the area, groundwater may rise to the surface through springs or seeps, flow laterally into nearby rivers, streams, or ponds, or sink deeper into the earth. In many parts of the world, groundwater is pumped out of the ground to be used for drinking, bathing, other household uses, agriculture, and industry.

Soil contamination
Contaminants in the soil can harm plants when they take up the contamination through their roots. Ingesting, inhaling, or touching contaminated soil, as well as eating plants or animals that have accumulated soil contaminants can adversely impact the health of humans and animals.

Air contamination
Air pollution can cause respiratory problems and other adverse health effects as contaminants are absorbed from the lungs into other parts of the body. Certain air contaminants can also harm animals and humans when they contact the skin. Plants rely on respiration for their growth and can also be affected by exposure to contaminants transported in the air.

Leachate
Leachate is the liquid that forms as water trickles through contaminated areas leaching out the chemicals. For example, the leaching of landfill can result in a leachate containing a cocktail of chemicals. In agricultural areas leaching may concentrate pesticides or fertilizers and in feedlots bacteria may be leached from the soil. The movement of contaminated leachate may result in hazardous substances entering surface water, groundwater or soil.

Thus, it can be stated that adverse impact on the environment is produced at all stages of waste management. In order to reduce environmental impact and health risks and optimize waste management system in general, this impact must be taken into account during the development of any waste management system.

Chapter 4
The Waste Management Hierarchy

4.1 Waste management hierarchy

In many European countries waste management did not become the responsibility of the government until the beginning of the 20th century. The main reasons for the government to intervene in the process of waste management were inadequate sanitary state of cities and people's health.

But as early as in the 80s and 90s of the 20th century, the principle of environmental protection based on capturing already formed contaminants, called "end-of-pipe treatment", was deemed inefficient.

In early 90s, many enterprises seriously concerned with environmental protection realized the necessity to introduce the following *principles* of environmental protection:

- reducing the use of resources and
- pollution prevention.

These principles were established in the waste management hierarchy which appeared in the first version of the European Framework Directive on waste in 1975.

Modern legislation and strategies of waste management in developed countries, including the EU, have switched from the traditional landfilling method to waste prevention at source (figure 4.1).

The principle of *pollution prevention* in the waste management hierarchy implies reducing waste generation at source. When further reduction is no more possible, ways and methods of waste reuse should be looked at. If reuse is not feasible, it may be possible to process or compost waste or recover materials or energy. Landfilling is an ultimate method of waste management, which must be used if none of the above stated methods can be applied. Using higher levels of the hierarchy means managing both waste and resources at large more rationally.

Defining the waste hierarchy stages

<u>Prevention</u> - measures taken before a substance, material or product has become waste that reduces:

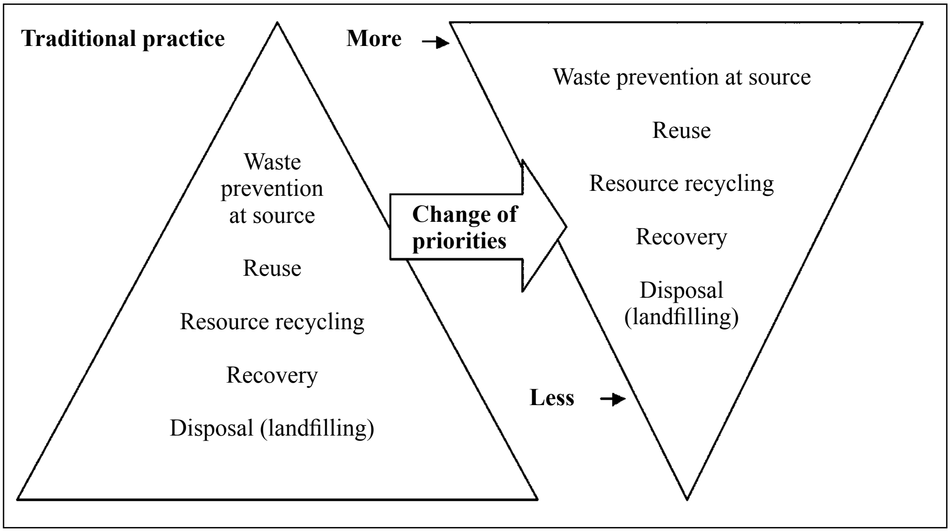

Figure 4.1 Change of priorities in waste management strategy

- the quantity of waste, including through the re-use of products or the extension of the life span of products;
- the adverse impacts of the generated waste on the environment and human health;
- the content of harmful substances in materials and products.

Re-use – any operation by which products or components that are not waste are used again for the same purpose for which they were conceived. Preparing for re-use - checking, cleaning or repairing recovery operations, by which products or components of products that have become waste are prepared so that they can be re-used without any other pre-processing

Recycling - means any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials.

Recovery - means any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfill a particular function, or waste being prepared to fulfill that function, in the plant or in the wider economy.

Disposal - means any operation which is not recovery even where the operation has as a secondary consequence the reclamation of substances or energy.

The waste management hierarchy has long been applied only in regard to waste generated after selling different products. However, the hierarchy really has a broader meaning and implies sustainable use of resources. The principle of end-of-pipe treatment must be combined with management strategies used at the beginning of the manufacturing process (e.g., changing the product's design or input materials can prevent waste generation or reduce the amount of waste).

The instruments of implementation of such waste management policy are taxes on virgin raw materials, eco-design of products, the requirements of EU Directives on Electronic and Electrical Waste, on Disposal of Vehicles, etc.

Probably, due to such broad application of the principles of waste management hierarchy, there have appeared some nuances concerning its interpretation and application:

- The principles of waste management hierarchy are often regarded as a strictly established order, where waste recovery is always more preferable than incineration, incineration is prior to landfilling, regardless of the cost, environmental impact and applicability of different waste management methods. Therefore, policies and plans concerning waste management focus on recovery and recycling of materials as opposed to energy recovery and landfilling.
- Otherwise, the waste management hierarchy is regarded as a general guiding principle for more flexible approach to the development of waste management strategy. Although the methods at the top of the diagram are the most preferable, a balanced system of MSW management requires all the hierarchy levels. Such waste management scheme is called the integrated one.

In 2004, to obtain a more accurate interpretation of the waste management hierarchy, one of the UK's leading recycling and waste management companies SITA carried out a research based on life cycle assessment and cost and efficiency analysis of different waste management methods. The outcomes are as follows:

- Recovery is the most preferable waste management method for such materials as aluminium, ferrous metals and glass. Recovery makes it possible to preserve natural materials and reduce the consumption of energy necessary for producing virgin materials.
- Recovery of paper, cardboard and plastic is less reasonable than energy recovery or even landfilling.
- Composting biodegradable waste can be both economically and socially beneficial when compost is used to replace peat.

The principles of waste management hierarchy must be applied while developing waste management policies, programs and guidelines. However, one of the main obstacles to fulfilling the hierarchy requirements is that waste managers cannot monitor the amount of generated waste, which hinders the application of the principle of reducing resources use. Therefore, for the hierarchy to be efficient, work should be done in two directions: towards the development of waste management system and the improvement of the production.

4.2 Waste management strategy and policy in EU

The history of environmental policy in the EU begins with waste policy. In the 1970s and 1980s a number of problems and scandals related to the handling of waste alerted policy-makers to the potential impact that poorly managed waste could have upon the environment and human health (see box).

The EU Member States began taking national measures to control and manage waste, which then led to the Waste Framework Directive and the Hazardous Waste Directive, both adopted in 1975, and later to the Waste Shipment Regulation. These three pieces of legislation put in place the basis of the regulatory structure on waste. They define waste and other key concepts, ensure waste is handled without causing damage to the environment or human health, and impose controlled conditions for moving waste throughout the EU.

In the late 1980s, a tightening of environmental regulations in industrialised countries led to a dramatic rise in the cost of hazardous waste disposal. Searching for cheaper ways to get rid of the wastes, “toxic traders” began shipping hazardous waste to developing countries and to Eastern Europe. When this activity was revealed, international outrage led to the drafting and adoption in 1989 of the Basel Convention, a multilateral environmental agreement. The Convention addresses cleaner production, hazardous waste minimisation and controls on the movement of these wastes, and meant that a number of unacceptable ways of dealing with waste, notably involving discharge at sea, were abandoned.

Box 4.1 The Seveso Waste Shipment scandal

In 1983, 41 barrels of dioxin waste turned up in an abandoned abattoir in Northern France. They contained heavily contaminated waste materials from a chemical plant in the town of Seveso, Italy, resulting from a chemical accident in1976. The toxic waste had been transported to the border safely, but had then disappeared. When eventually located, the barrels had been lost in France for over eight months.

However, the first EU Directives did not specify the environmental emission parameters for the various waste management options that were considered to be acceptable: landfill, incineration and recycling. This proved to be the weak point in terms of environmental damage from waste, as was shown by a number of problems involving pollution from incinerators or landfills, and from certain recycling plants.

Most of these gaps were filled by the Landfill Directive, finally adopted in 2001, and by the Waste Incineration Directive of 2000 and its precursor legislation. Standards were set in terms of pollution into the air or into groundwater. In addition, the 1996 Directive on Integrated Pollution Prevention and Control (IPPC), which introduces a permit system to tackle pollution from industrial and agricultural facilities, sets standards for a number of waste-related activities, as well as for plants where waste can be used, such as cement kilns.

The next major step was to help improve the management of waste, and in particular to promote recycling, re-use and energy recovery over the disposal of waste. The 1996 Waste Strategy Communication from the European Commission:

- reinforced the notion of a waste hierarchy;
- re-affirmed the "polluter pays" principle with regard to waste (so that those who produce waste should have to pay the cost of treatment);
- developed the concept of priority waste streams.

There were waste streams where current practices had a high environmental impact, or where it had proved particularly difficult to organise the funding of recycling despite the clear environmental benefits. Over the last ten years or so this has resulted in legislation on packaging and packaging waste, on end-of-life vehicles and on waste electrical and electronic equipment.

Turning waste into a resource is one key to a circular economy. The objectives and targets set in European legislation have been key drivers to improve waste management, stimulate innovation in recycling, limit the use of landfilling, and create incentives to change consumer behavior. If we re-manufacture, reuse and recycle, and if one industry's waste becomes another's raw material, we can move to a more circular economy where waste is eliminated and resources are used in an efficient and sustainable way.

Improved waste management also helps to reduce health and environmental problems, reduce greenhouse gas emissions (directly by cutting emissions from landfills and indirectly by recycling materials which would otherwise be extracted and processed), and avoid negative impacts at local level such as landscape deterioration due to landfilling, local water and air pollution, as well as littering.

In line with this the 7th Environmental Action Programme (2013), main environmental strategy document, sets priorities and goals till year 2020, established the following priority objectives for waste policy in the EU:

- To reduce the amount of waste generated;
- To maximise recycling and re-use;
- To limit incineration to non-recyclable materials;
- To phase out landfilling to non-recyclable and non-recoverable waste;
- To ensure full implementation of the waste policy targets in all Member States.

The main elements of the waste management strategy and goals are including:

- Recycling and preparing for re-use of municipal waste to be increased to 70% by 2030;
- Recycling and preparing for re-use of packaging waste to be increased to 80% by 2030, with material-specific targets set to gradually increase between 2020 and 2030 (to reach 90% for paper by 2025 and 60% for plastics, 80% for wood, 90% of ferrous metal, aluminium and glass by the end of 2030);
- Phasing out landfilling by 2025 for recyclable (including plastics, paper, metals, glass and bio-waste) waste in non hazardous waste landfills – corresponding to a maximum landfilling rate of 25%;
- Measures aimed at reducing food waste generation by 30% by 2025;
- Introducing an early warning system to anticipate and avoid possible compliance difficulties in Member States;
- Promoting the dissemination of best practices in all Member States, such as better use of economic instruments (e.g. landfill/incineration taxes, pay-as-you-throw schemes, incentives for municipalities) and improved separate collection;
- Improving traceability of hazardous waste;
- Increasing the cost-effectiveness of Extended Producer Responsibility schemes by defining minimum conditions for their operation;
- Simplifying reporting obligations and alleviating burdens faced by SMEs;
- Improving the reliability of key statistics through harmonized and streamlined calculation of targets;
- Improving the overall coherence of waste legislation by aligning definitions and removing obsolete legal requirements.

4.3 Waste strategy in the Republic of Uzbekistan

The basis for choosing directions and coordination of work concerning waste management in Uzbekistan is provided by the National strategy and Waste management action plan (2005). The strategy is aimed at implementing the state policy and increasing the efficiency of activities in the waste management system. It prioritizes reduction, reuse and recycling of solid waste. Measures taken are aimed at preventing loss of valuable substances and materials with waste, avoidance of further pollution of the environment with toxic industrial and medical waste and solving the problem of accumulation and disposal of MSW.

The National strategy of the Republic of Uzbekistan defines efficient ways to improve the environment in the country by means of organizing and creating a system of waste management. The National strategy conforms to the main directions of the environmental policy and also factors in the long-term economic and social policies. The National strategy aims at forming the strategy of prevention and elimination of adverse impact produced by generated and disposed waste on the environment and human health, as well as maximum involvement of waste in the production cycle. The National waste management strategy of the Republic of Uzbekistan is based on the following principles and provisions:

- The highest priority for any economic and political solution is protection of human health and the environment paired with preventive and operational measures;
- Combined administrative and economic measures are applied to prevent environmental degradation and pollution in the course of waste management ;
- Efficient participation in the international cooperation aimed at solving national, transboundary and global problems concerning waste management.

Step-by-step fulfilment of the tasks stated in the strategy is secured by the National environmental protection action plan (2013), as well as a range of resolutions passed by the government, the state environmental protection committee of Uzbekistan and other national guiding documents.

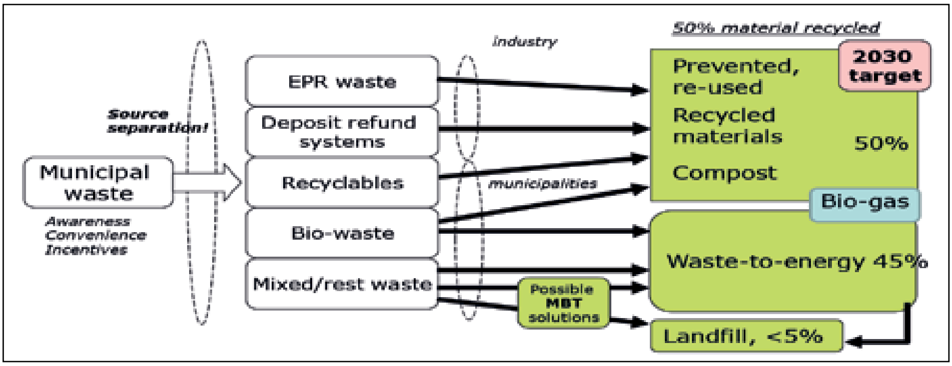

Figure 4.2 Main directions and aims of work concerning waste management in the EU (2013).

The Republic of Uzbekistan seeks to study and apply the experience of other countries in waste management sector. There are several ongoing projects in the country aimed at developing MSW collection and transportation system.

An example is an investment project on the modernization of waste recycling infrastructure launched with a view to improve MSW collection and transportation system and the epidemiologic situation in Tashkent. The project is implemented with a loan from the Asian Development Bank. Negotiations are also under way to get a loan from French Development Agency to improve the sanitary purification system in the historical and spiritual centre of Uzbekistan – the city of Samarkand. The implementation of the above mentioned projects will help improve the full cycle of waste collection and transportation system, from waste generation to landfilling, waste separation system, waste recycling and will also supply the existing car and machine park with modern refuse collectors.

Prospective lines of policy regarding the improvement of municipal solid waste management system in Uzbekistan

Government authorities dealing with waste management in Uzbekistan, businesses and public organizations consider it necessary to create incentives for increasing the efficiency of waste management systems, e.g. relaxed taxation for legal entities and sole proprietors who manage waste collection, transportation and disposal, or entitlement payments for MSW collection. Incentives must be created to attract direct foreign investments into the waste management system. Partnership between private and state entities can also help develop the infrastructure of the waste management system in urban and rural areas based on the modern planning principles. It is reasonable to implement awareness raising measures aimed at informing urban population on the issues concerning environmental protection and efficient waste management.

4.4 Regional and local waste management plans

The development of national or regional, as well as local waste management plans is stipulated by the Directive on waste (for the EU-states) or national legislative acts. A range of other EU Directives describe different aspects to be included in such plans.

National waste management plan is usually a strategic document, which does not set specific aims, while regional and local plans are mostly oriented at practical actions and provide sufficient detailed descriptions of the existing MSW collection systems, treatment facilities, etc.

To make political tasks feasible and measurable, they must be transformed into targets. Regional and local waste management targets stated in the corresponding plans must be set according to the waste management hierarchy. Besides, these targets must conform to the national waste management strategy and solve local problems.

Prior to the development of the plans, the existing system of waste collection and recycling must be assessed from the physical, financial and organizational aspects. Such analysis helps to reveal whether the previously set targets – e.g. waste recycling target, target for collection of certain waste categories or compliance with European standards on waste treatment facilities – have been accomplished. Such assessment must be based on thoroughly collected data and general information on waste streams, amount of their generation, their types, collection, transportation, recycling and disposal, as well as the structure of the existing system.

If waste management plan is developed on the basis of previous plans, it is important to take into account whether previously set targets have been accomplished and if there is any evidence that they can be achieved in the near future. I.e. in some cases it is necessary to adapt and review prior targets or measures taken to accomplish them.

Sustainable development of waste management systems requires considerable financial resources. Financing methods vary greatly in different European countries: collection and transportation, running waste treatment facilities and MSW landfills can be financed and organized by state or private enterprises, cross-municipal alliances, etc. The financing of waste management system depends on the national legislation and on how producers pay for waste disposal. Waste collection and transportation expenses are often covered by taxation system, while other financing systems, e.g. based on extended producer's responsibility, are only used for certain waste streams.

Waste management responsibilities can be shared by several stakeholders, e.g. between municipalities and businesses. In some cases producer is charged with the responsibility to collect and recycle generated waste, which is usually enforced by law or various agreements.

Regardless of the existing distribution of responsibilities, the action plan must provide detailed information on each waste stream and assign people or organizations in charge of them.

The decisive role in developing waste management plans belongs to political support and accepting the need for such plan. From the practical aspect, waste management action plan should be long-term enough to assess the results of its implementation. Therefore, action plans should not be reviewed sooner than three years after adoption. The time frame of the plan can also vary depending on political factors, e.g. the gap between elections to the local authorities.

Participation of different stakeholders and the public in the planning process ensures that the environmental policy will be easily accepted and the targets set will be efficiently fulfilled. The degree and manner of participation of different stakeholders are often determined by cultural traditions and political structure of the country.

4.5 Informing and public involvement

Improving MSW management system implies the introduction of new technologies, e.g. sorting municipal waste at source. To make the system efficient and economically sound, it is necessary to collaborate with waste producers. Such collaboration is facilitated through a series of coordinated educational and informational events for the public, aimed at explaining their responsibilities to waste producers and rendering them support and help. Public involvement in MSW management system requires transparency of decisions concerning waste management, which will benefit the whole system, too.

Informational and educational campaigns

Informational and educational campaigns are organized to accomplish the following goals:

- To show what adverse impact on the environment is produced by waste generation and management processes that do not comply with legal requirements;
- To make the public realize their responsibility for MSW they produce;
- To encourage waste producers to participate in waste management processes for the waste they produce;

Informational and educational strategies are to be designed with the following issues in view:

- The ultimate goal of informational and educational campaigns is to change waste producers' behavior.
- Information must be provided in an active and demonstrative form;
- Communications must be aimed at persuading waste producers in the necessity to participate and collaborate in MSW management processes.

Media campaigns

Announcements in media (television, radio, printed media, Internet) and on billboards are employed when the activity described is hindered by only insignificant

Figure 4.3 Informing residents on the correct separation of waste at source is, probably, one of the key components of the collection system. Such memos placed at garbage collection sites in multi-family houses and waste collection "stations" around the city of Stockholm "hint" people what wastes must be put into each of the garbage containers.

obstacles, while the expected benefits are seen as considerable. Advertising encourages open dialogue and reminds on the necessity to take actions. The communicated messages are usually expressed in a positive form so that not to sound like a dull homily (figure 4.4).

Another method is media-releases and press-conferences covering innovations in the MSW management system.

Where possible, informational and educational campaigns must be based upon or include direct contacts with target groups, e.g. through organizing meetings in residential committees, schools, etc.

Figure 4.4 An informational stand from Minsk, Belarus, encouraging the public to start collecting waste separately

Non-governmental organizations (NGOs) usually have established contacts and efficient means of communication with the population, therefore, they should be involved in conducting informational and educational campaigns.

A good effect is usually produced by media demonstrations of various objects manufactured from recycled materials. This makes it possible to attract public attention and present information in an interesting and unexpected way.

School campaigns

School education is regarded to be the best means of awareness raising. Many municipalities introduce into school curriculums subjects devoted to waste minimization, recycling, composting and other methods of waste management. Children are engaged in getting environmental education as the generation which is to make the necessary changes in public conscience. Besides, even without realizing that, children make adults think about waste problems, since they tend to discuss everything they learn at school with their parents. Finally, children have not developed a rigid behavior model, and therefore, can be easily persuaded to act correctly.

Campaigning at school makes it possible to deliver the following information to students (and to a certain extent – to their parents):

- the concept of sustainable waste management;
- the adverse impacts produced on the environment, natural resources and human health by all inadequate methods of waste management;
- the necessity and possible ways of public involvement I waste management and waste separation at home.

School campaigns can be based upon:

- teaching materials for ecology lessons, etc.;
- contests of essays/ pictures on the topics related to waste management. This will focus teachers' and pupils' attention on the existing problems and their possible solutions;
- ideas concerning the organization of waste recycling systems at schools;
- excursions to waste treatment facilities;
- community work days, etc.

In Uzbekistan there have also been conducted a range of successful and promising informational and educational campaigns for schoolchildren devoted to waste management problems. An example of such campaigns is a contest for the best picture depicting waste management problems. The contest was announced on the radiochannel Uzbekiston and a range of national media. The main criterion for choosing best pictures was an uncommon approach to the problem of protecting people and nature from the adverse impact of waste. More than 100 pictures of schoolchildren from almost all regions participated in the contest. The awarding ceremony was conducted during the seminar “Ways of raising public awareness on the issues concerning waste management” (March 2006, Tashkent). All the participants were awarded with valuable prizes, and the winners got diplomas.

Chapter 5
Legal Frameworks and Economic Instruments

5.1 Basel Convention

The cross-border transport of hazardous wastes seized the public's attention in the 1980s. The misadventures of "toxic ships" such as the Katrin B and the Pelicano, sailing from port to port trying to offload their poisonous cargoes made the front-page headlines around the world. These tragic incidents were motivated in good part by tighter environmental regulations in industrialized countries. As the costs of waste disposal skyrocketed, "toxic traders" searching for cheaper solutions started shipping hazardous wastes to Africa, Asia and other regions. Once on shore, these waste shipments were dumped indiscriminately, spilled accidentally or managed improperly, causing severe health problems -even death- and poisoning the land, water and air for decades or centuries. To combat these practices, the Basel Convention was negotiated under the auspices of the United Nations Environment Programme in the late 1980s. It was adopted in 1989 and entered into force in 1992.

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal aims to protect human health and the environment against the adverse effects of the generation, management, transboundary movement and disposal of hazardous and other wastes. The Basel Convention is the most comprehensive global environmental agreement on hazardous wastes and other wastes. Among other matters, the convention regulates transboundary movements of hazardous wastes and other wastes. Parties to the Basel Convention have the overall obligation to ensure that such movements are minimized and that any movement is conducted in a manner which will protect human health and the environment. In addition to these general obligations, the Convention provides that transboundary movements can only take place if certain conditions are met and if they are in accordance with certain procedures. It is the Competent Authorities designated by Parties that assess whether the Basel Convention requirements for transboundary movements are met.

5.2 European Union legislation on waste

The European Union legislation on waste, including MSW management, is one of important components of the EU legislation. It must be mentioned that this legislation is paid much attention due to the serious character of the issue.

Basic legal acts regulating waste management in the EU include:

The Lisbon Treaty, environment and waste

The Lisbon Treaty, the Treaty on the Functioning of the European Union (2007), an international agreement which amends the two treaties which form the constitutional basis of the European Union, states that the environment should be a policy of shared competences between the Union and the Member States (Art. 4(2)(e). The Treaty of Lisbon clarifies that one of the Union's objectives is to work for the sustainable development of Europe, based in particular, on high level of protection and improvement of the quality of the environment. Although the idea of sustainable development was included in the previous treaties, the Treaty of Lisbon reinforces and defines this objective better. With the Treaty of Lisbon, combating climate change also became a specific objective of EU environmental policy.

The European Union's environment policy is based on Article 191 of the Treaty of Lisbon. It aims to preserve, protect and improve the quality of the environment and to protect human health. It also focuses on the careful and rational use of natural resources and to tackle climate change. It is based on the precautionary, preventive action, correction at source and "polluter pays" principles.

Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on Waste and repealing certain Directives (Waste Framework Directive – WFD)

The Directive establishes a legal framework for the treatment of waste in the EU. It sets the basic concepts and definitions related to waste management and lays down waste management principles for all other EU legislation related to waste, such as the "polluter pays principle" and the "waste hierarchy". This Directive includes two new recycling and recovery targets to be achieved by 2020: 50% preparing for re-use and recycling of certain waste materials from households and other origins similar to households, and 70% preparing for re-use, recycling and other recovery of construction and demolition waste. The Directive requires that Member States adopt waste management plans and waste prevention programmes. It sets the framework for waste management in Member States, including the extended producer's responsibility. This Directive amended previous Waste Framework Directive 2006/12/EC and came into force on December 2010.

Figure 5.1 Separate waste collection system in a dwelling sector in Uppsala (Sweden). Waste separation by fractions (organic, plastic, paper and cardboard, glass, metal) starts in the kitchen with the help of simple accumulators. Large enough containers for disposal of separately collected waste are placed near houses.

Presented below are some other legal acts regulating the management of certain specific categories of waste and waste management operations:

Council Directive 1999/31/EC of 26 April 1999 on the Landfill of Waste
The Directive is intended to prevent or reduce the adverse effects of the landfill of waste on the environment. It defines the different categories of waste (municipal waste, hazardous waste, non-hazardous waste and inert waste) and applies to all landfills. Landfills are divided into three classes: landfills for hazardous waste; landfills for non-hazardous waste and landfills for inert waste. The Directive obliges Member States to minimize biodegradable waste to landfills to 75% by 2006, 50% by 2009 and 35% by 2016, and to treat it before disposal. The Directive also defines wastes which are not to be accepted in any landfill and sets up a system of operating permits for landfill sites. The Directive comes fully into force on 16 August 2009.

Directive 2000/76/EC of the European Parliament and of the Council of 4 December 2000 on the Incineration of Waste (WID)
The European Union imposes strict operating conditions and technical requirements on waste incineration plants and waste co-incineration plants to prevent or

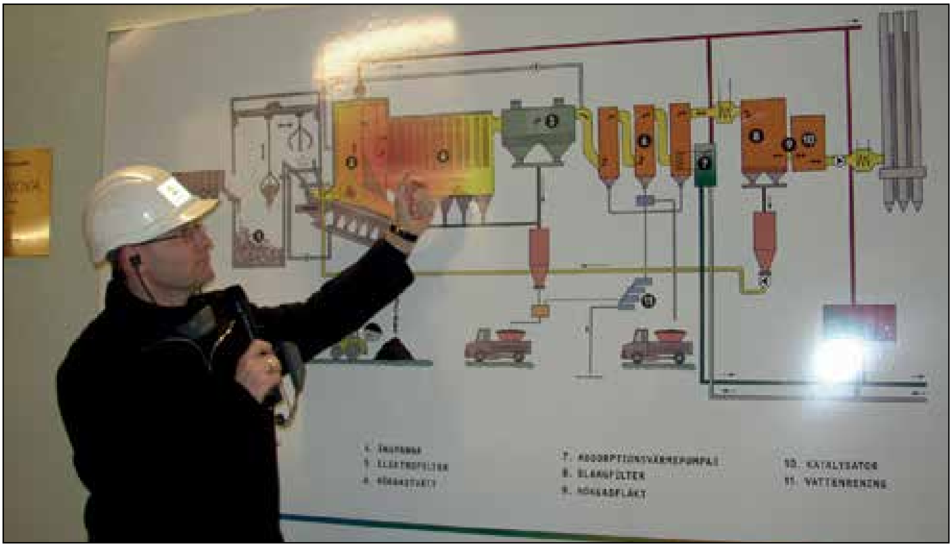

Figure 5.2 Waste incineration plant in Uppsala is one of many similar plants operating in Sweden. The enterprise produces electricity and heat for the city and suburb with the population of about 500 thousand people. Environmental protection is the primary concern of the enterprise.

reduce air, water and soil pollution caused by the incineration or co-incineration of waste. The directive requires a permit for incineration and co-incineration plants, and emission limits are introduced for certain pollutants released to air or to water.

European Parliament and Council Directive 94/62/EC of 20 December 1994 on Packaging and Packaging Waste

The Directive sets out measures and requirements for the prevention, re-use and recovery of packaging wastes in Member States. It seeks to harmonise national measures concerning the management of packaging and packaging waste to provide a high level of environmental protection and ensure the functioning of the internal market. Member States must ensure that packaging placed on the market complies with the essential requirements: to limit the weight and volume of packaging to a minimum; to reduce the content of hazardous substances; to design reusable or recoverable packaging. The Directive implies the producer responsibility principle.

Directive 2012/19/EC of the European Parliament and of the Council of 4 July 2012 on Waste Electrical and Electronic Equipment (WEEE Directive)

This Directive aims to provide incentives to improve the design of electrical and electronic equipment to facilitate recycling. It was introduced to prevent the generation of electrical and electronic waste and to promote reuse, recycling and other forms of recovery in order to reduce the quantity of such waste. It shifts responsibility for WEEE to the *producers*, giving them the obligation to recycle electrical and electronic equipment that consumers return to them free of charge.

Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (ROHS Directive)
This Directive covers the same scope as the WEEE Directive (except for medical devices and monitoring and control instruments). This Directive requires the substitution of various heavy metals by other substances in new electrical and electronic equipment entering the market. Every four years the Commission undertakes an assessment of the exemptions in order to check whether the exemptions are still justified in light of technical and scientific progress. Member States are to determine the penalties applicable to breaches of this Directive. This is a product Directive, not a waste Directive.

Directive 2006/66/EC of the European Parliament and of the Council of 6 September 2006 on Batteries and Accumulators and Waste Batteries and Accumulators and repealing Directive 91/157/EEC
The Directive prohibits the placing on the market of most batteries and accumulators with a certain mercury or cadmium content and establishes rules for the collection, recycling, treatment and disposal of batteries and accumulators. The aim is to cut the amount of hazardous substances, in particular, mercury, cadmium and lead, dumped in the environment; this should be done by reducing the use of these substances in batteries and accumulators and by treating and re-using the amounts that are used. The Directive implies the *producer responsibility principle*.

Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on End-of-Life Vehicles
The Directive aims to limit the production of waste arising from end-of-life vehicles and to increase re-use, recycling and recovery of end-of-life vehicles and their components. The generation of waste from vehicles should be avoided as much as possible. The Directive establishes a collection rate for re-use and recovery of 85% by 2006 and 95% by 2015. While the rate for re-use and recycling has been set up to 80% by 2006 and 85% by 2015. The Directive implies the manufacturers product responsibility.

Figure 5.4. In the European Union household batteries are often collected in shopping malls. A customer, who has come to buy some food, can discharge useless batteries into a special marked container located in the supermarket. Further collection and recycling is conducted by a specialized waste management organization (usually the one in charge of all the stages of municipal waste management).

Directive 2005/64/EC on the Type-approval of Motor Vehicles with Regard to their Re-usability, Recyclability and Recoverability
The Directive requires vehicle manufacturers to comply with minimum thresholds for the re-use, recycling and recovery of the component parts and materials of new vehicles. The aim is to ensure that vehicles are designed to facilitate processing at the end of their life cycle. In accordance with this Directive, vehicles may be put on the market only if they are re-usable and/or recyclable to a minimum of 85% by mass or are re-usable and/or recoverable to a minimum of 95% by mass. This is a manufacturer's product responsibility.

Council Directive 86/278/EEC of 12 June 1986 on the Protection of the Environment, and in Particular of the Soil, when Sewage Sludge is Used in Agriculture
The Directive regulates the use of sewage sludge in agriculture to prevent harmful effects on soil, vegetation, animals and humans. In particular it sets maximum values of concentrations of heavy metals and bans the spreading of sewage sludge when the concentration of certain substances in the soil exceeds these values. Sludge from small sewage-treatment plants, which treat primarily domestic waste water, can represent danger to the environment.

Directive 2010/75/EU on Industrial Emissions (IED)
The IED is the successor of the IPPC Directive. It concerns the minimization of pollution from industrial activities, defined in Annex I of the Directive. Operators

of these industrial installations are required to obtain an integrated permit from the authorities in the EU countries and meet certain basic obligations. The IED entered into force on 6 January 2011 and must be transposed into national legislation by Member States by 7 January 2013.

Regulation (EC) No 1013/2006 of the European Parliament and of the Council of 14 June 2006 on Shipments of Waste
This Regulation aims at strengthening, simplifying and specifying the procedures for controlling waste shipments to improve environmental protection. It sets out a system of control for the movement of waste. The Regulation specifies the documentation to be provided and the security measures to be taken during transportation. The system must take into account the principles of self-sufficiency, proximity of waste for disposal and prior informed consent. This should reduce the risk of waste shipments not being controlled. The Regulation concerns almost all types of waste shipped, including national and transit transports, except radioactive waste and a few other types of waste. It is based on the International Basel Convention.

Directive 2006/21/EC of the European Parliament and of the Council of 15 March 2006 on the Management of Waste from Extractive Industries (Mining Directive)
The Directive aims at minimizing negative effects on the environment and human health from the treatment and disposal of mining and quarrying waste. This is the Waste Directive for mining waste which is exempted from the WFD. This extractive waste must be managed in specialised facilities in compliance with specific rules. Operators of such facilities are subject to liability in respect of environmental damage caused by their operation. Member States shall take every precaution to limit risks to public health and the environment related to the operation of extractive waste processing facilities, inter alia by applying the concept of "best available techniques". The Directive covers the planning, licensing, operation, closure and after-care of waste facilities and provides for a major-accident policy for high-risk facilities. Inventories of closed facilities posing serious risks to the environment and health have also to be drawn up by Member States.

5.3 The German waste law as an example of advanced regulation

The objective of the German government's policy on waste is to achieve a recycling-based economy that conserves resources and reduces adverse impacts on the environment. The aim is to increase and optimize the efficient use of raw materials, to maximize recovery quotas and to permanently remove from our environment any residual waste that can no longer be used. This will lead to a substance management within closed substance cycles, i.e. turning today's trash into tomorrow's treasure-trove. Activities on waste are part of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety's action programme to increase the productivity of resources.

Waste management legislation is based on European law, German federal law, the regional laws of the federal states and the statutes of the local authority waste management services. It is also based on the precautionary principle, the polluter-pays principle and the principle of co-operation. The main pillar is the Closed Substance Cycle and Waste Management Act. This act will be further developed by the end of 2010 on the basis of the new EU Waste Framework Directive in order to strengthen waste prevention and recovery. Through this act, industry and the commercial sector have been made responsible for the recovery of waste, i.e. they also have to bear the costs. All waste from private households and waste for disposal from other generators has to be passed on to waste institutions subject to public law; for this service, fees have to be paid. For waste destined for disposal, it has been stipulated that priority should be given to disposal within Germany (self-sufficiency principle), whilst waste destined for recovery underlies the free movement of goods within the EU.

The enforcement of waste legislation in Germany is mainly the task of the federal states. It is governed by requirements for waste supervision contained in the Closed Substance Cycle and Waste Management Act and supported by requirements on waste recovery and disposal records, transport licenses and specialized waste management companies.

Germany's first uniform national waste disposal act was adopted in 1972. The Waste Management Act, which is today Germany's main waste disposal statute, incorporates the main structural elements of the Closed Substance Cycle and Waste Management Act.

The Closed Substance Cycle and Waste Management Act aims to ensure the complete prevention and recovery of waste, including hazardous waste. Thus, prevention takes precedence over recovery, which in turn comes before disposal. Waste prevention is implemented inter alia through extended producer responsibility, which on the one hand involves developing products and substances with the longest possible service life and, on the other, introducing production techniques that generate the minimum possible volume of waste through best available techniques (BAT) requirements as part of a permitting system for industrial installations. Under extended producer responsibility, producers of a commodity are required to consider the environmental impacts and possible risks of a product during its entire life-cycle (precaution). In collaboration with the other parties involved – producers, distributors, consumers, disposal and recycling companies, government offices (co-operation) – the producer is required to create a system that minimizes the adverse environmental impacts and maximizes the recovery of resources (recycling, reuse).

The centerpiece of Germany's Waste Management Act is a five-level waste hierarchy that lays down a fundamental series of steps comprising waste prevention, reuse, recycling, and other elements besides, including energy recovery, and finally waste disposal. In any given instance, the best option from an environmental protection standpoint always takes precedence, whereby ecological, technical, economic and social effects are to be taken into account as well. Thus waste management practices in Germany systematically aim to minimize waste generation and maximize recycling, while at the same time ensuring that the remaining waste is disposed of in a manner consistent with the common welfare.

In Germany, a number of laws and regulations, in addition to the Closed Substance Cycle and Waste Management Act, contain provisions on recovery, reuse and recycling for the following wastes: packaging, batteries, waste electrical and electronic equipment, end-of-life vehicles, waste oil, biodegradable waste, waste wood, sewage sludge, commercial municipal waste, waste going to incineration, waste recovered at surface landfills and waste going to underground stowage.

Glass, paper, old clothes, compost and biowaste, packaging, electrical and electronic waste, batteries, metal, bulky waste and hazardous waste from private households are collected separately before they are recycled by the producers of new products or by private or public sector agencies. For example, in 2006 on average over 8 kilograms of waste electrical and electronic appliances per inhabitant and year was collected from private households, more than twice as many as required by the related EU Directive .

Because of the high standards imposed on recovery, waste that has been separately collected still needs to be further sorted. This sorting is mainly performed automatically using, for example, a refined detector system based on near infrared spectrography in order to separate different types of plastic with a high degree of accuracy.

For example, the Ordinance on Biowaste ensures that only biodegradable waste with a low pollutant content is utilized as a source material for fertilizers or soil improvers, for example, after composting or fermentation. The aim is to recycle organic material and to avoid the accumulation of pollutants in the soil. An average of about 50% of the population in Germany collects bio-

Figure 5.5. Automatic waste sorting station in Hamburg, Germany

waste by using bio-bins. The separate collection of suitable biowaste should be expanded.

Sewage sludge from local authority sewage treatment plants contains high levels of phosphorous. That is why around 30% of sewage sludge is currently used as a source material for fertilizers. The German government is also promoting techniques for extracting low-pollutant phosphate from sewage sludge and domestic sewage to increase the ratio of recycled phosphor.

The Waste Wood Ordinance sets out concrete requirements governing the recycling, energy recovery and disposal of waste wood and ensures that pollutants are not recycled or do not accumulate during recovery.

In addition, there are voluntary commitments by the industry for construction and demolition waste and for graphic paper.

There has been a clear shift towards more recovery and recycling. The population's willingness to separate its waste has helped to reinforce this trend.

The Landfill Ordinance sets high standards for landfill sites. It also requires extremely hazardous waste to be disposed of below ground in deep salt mines. Compared to about 2,000 in the 1980s, today only about 160 landfill sites for municipal waste exist in Germany. This number will be further decreased.

The provisions on landfills in Germany are much stricter than required by the EU Landfill Directive. Since June 2005, residual waste from households and industry must be treated in such a way as to prevent biological conversion processes from occurring in landfills. This presupposes that the residual waste is pre-treated. The most part of the residual waste is treated by high-standard waste-to-energy plants; the rest is treated by high-standard mechanical-biological treatment. In this way, the generation of landfill gas is reduced to almost zero. This has led to a reduction of more than 30 million tonnes of carbon dioxide equivalents per year. The substitution of fossil fuels through the non-recyclable biogenic part of residual waste in waste-to-energy plants leads to a yearly reduction of round about 4 million tonnes of carbon dioxide equivalents. Thus sustainable residual waste management makes an important contribution to climate protection in Germany.

The waste incineration ordinance, based on the Federal Emission Control Act, contains high standards for the incineration and co-incineration of waste.

The provision of facilities for waste treatment and disposal is led mainly by the private sector, including for small- and medium-sized industries.

The Waste Management Act is supplemented and fleshed out by a number of other regulations which lists the types of waste that are classified as hazardous, and those that are classified as non-hazardous. Also these regulations flesh out the monitoring provisions.

5.4 Economic instruments

Economic instruments work with economic incentives to influence the behavior of consumers and producers. Economic instruments compared to other types of policy instruments (e.g. command-and-control instruments) leave a larger degree of freedom to individuals to make the environmental improvements in the most cost-effective manner. Also, administrative costs of implementing economic instruments tend to be significantly lower than those associated with the monitoring of compliance with command-and-control regulation. In the waste management sector, economic instruments can contribute to strengthen waste management systems and the "polluter-pays-principle" by providing revenue – either through user charges or through taxes and charges on waste generation or disposal that can be earmarked for waste management services. Apart from fiscal objectives, economic instruments in the waste management sector can also help to further a number of environmental objectives like reducing waste generation, increasing separated collection and recycling of household waste as well as diverting waste streams from landfill disposal. There are following economic instruments mostly used: *municipal waste charges, landfill taxes, landfill permit trading schemes, deposit-refund schemes and Advanced Recycling Fees*.

Municipal waste charges, depending on their design, can make a meaningful contribution to waste reduction and better waste separation. Depending on how charges are calculated for the individual user, they can be differentiated into flat-rate user charges, service-unrelated variable-rate user charges, and service-related variable-rate user charges (unit-pricing). The latter have significant potential to create incentives for waste reduction and improved separation. The most significant impact on waste generation and separated collection is coming from weight-based systems of user charges. However, collection and billing systems needed for weight based charging are comparably complicated and costly. Container subscription systems, where households can choose from different size containers create a modest incentive for waste minimization and better separation but are comparably easy to manage. A promising model that creates significant incentives for waste reduction and better separation and is comparably easy to manage at the same time is a pre-paid garbage bag model. There is a potential trade-off between strong environmental incentive effects of waste charges and the stability of revenues derived from them. The more accurately the charge adapts to the actual amount of waste collected, the more room there is for temporary revenue volatility. This trade-off can partly be overcome by introducing hybrid systems of waste charges, where one component is a flat-rate charge which covers part the structural costs of waste management services and the other a variable part depending on the amount of waste collected.

Landfill taxes are an effective instrument to correct market failures and help internalize external costs, which are caused by the dumping of waste through methane emissions, potential leakage of fluids, amenity costs to neighboring communities and increased transport. Through the price signal, landfill taxes can contribute to diverting waste streams away from landfills to recycling. The effectiveness of the environmental incentive of landfill taxes depends on the tax rate. Most of countries introduced landfill taxes together with command and control instruments like landfill bans for certain substances or more ambitious landfill standards. Hence, it is difficult to separate diversion effects by the landfill tax proper. Like with most environmental taxes the administrative costs for landfill taxes are comparably low. Revenues from landfill taxes can be used to fund activities improving waste management and recycling activities.
While the landfill tax addresses the problematic effects of landfilling by internalizing the negative external effect and by creating incentives to divert waste streams to other modes of treatment and recycling, another possibility is to address this problem through a trading scheme. To date the UK is the only country which has introduced a landfill permit trading scheme for biodegradable municipal waste. The Landfill Allowances and Trading Scheme (LATS) sets a limit on

the amount of biodegradable municipal waste that each waste disposal authority can send to landfill. It has been proven successful in allowing municipalities a performance corridor during which they were limiting their disposal of biodegradable waste in landfills in order to reach the target of the respective EU Directive in a cost-efficient manner.

Deposit-refund systems are in place in a number of countries to create incentives for returning products after the end of their useful-lives. These systems can be implemented, where the product or its packaging does keep its integrity throughout its life-cycle and/or where there is a significant risk of illegal dumping even if households face no direct charge for waste collection and disposal, or where the costs of illegal dumping are high (as in the case of toxic products). Most commonly, deposit-refund systems are implemented for bottles, but sometimes also for potentially hazardous products like batteries. The incentive is created by asking customers to pay a deposit when buying the product concerned and refunding them the same amount upon return of the product. The objective of deposit-refund systems is to make sure that valuable materials are not disposed of but incorporated in a recycling or re-use scheme. They have proven very successful in increasing collection and re-cycling rates for the products which they are covering. Deposit-refund systems usually address specific products and usually burden the administrative costs on the industry. This increases the probability of significant lobbying and resistance from the affected industry.

Advanced Recycling Fees (ARFs) are fees paid by the consumer on product sales and used to cover the cost of recycling. ARFs are often assessed per unit of the product sold but can also be assessed on a weight basis. The objective of ARFs is to internalize the costs of the recycling of products after the end of their useful lives already in the purchasing price and thus to guarantee that prices better reflect products' life cycle costs. Advanced Recycling Fees have proven successful in Japan and California to provide funding for the recycling of certain products like electronic goods or end-of-life vehicles. While they do not create an incentive for increased recycling (this is done through mandatory recycling quotas) they generate revenues for the recycling process. From a social perspective ARFs burden the costs of recycling on the consumer.

Flexible taxation systems
Flexible taxation systems are an important instrument in national, regional and local waste management systems. They have become widely used in Europe. In

most countries applying flexible taxation systems their disadvantages are surely compensated by the following advantages:

- reduction of municipal waste generation by 15-50%;
- increase of waste sorting (5-10%);
- appreciable growth of home-composted waste (the exact figures are difficult to estimate);
- reduction of solid waste generation in general, especially due to the minimization of MSW and the growth of composting levels (3-12%).

In general, the application of flexible taxation systems can be based upon the volume or weight of generated waste. These systems differ in the requirements for the design of waste management systems and the equipment used.

The system of taxation based on the *volume* of generated waste means that the size of the tax is determined according to the volume and quantity of garbage containers used by a household.

This system can be implemented through one of the schemes:

- the tax size is determined according to the number of garbage containers and bags left at the curbside;
- residents are obliged to buy special bags (or labels and stickers for garbage bags), and waste collection expenses are included in the price.

The system of taxation based on the *weight* of generated waste means that municipalities weigh collected garbage bags and containers and determines a certain tax sum per unit of weight. In this case residents can either use their own garbage containers or are obliged to buy standard containers produced by municipalities.

In many developed countries this principle is known as “pay-as-you-throw“(PAYT). It is a proportional system of payment for waste disposal. This principle encourages the growth of life philosophy focused on waste prevention and separate collection. This system ensures fair payment, when people only have to pay for the amount of waste they produce and the cost of its disposal. Direct correlation between the amount of waste and the size of payment motivates people to produce less or no waste and to switch to reuse, which is more economically favourable.

PAYT system is opposed to previously used financing method, when the costs of waste management were covered by regular payments or taxes or/and fees depending on the size of land site, the number of people in the household, etc. PAYT means that waste management services and, accordingly, the consumption of natural resources must be paid for in the same manner as, for example, water or electricity consumption.

To implement this fair payment system according to the principle "producer pays" it is necessary:

- to measure the quantity of generated waste or the volume of the service used;
- to provide specific identification to oblige the producer to pay the expenses
- to determine the size of fees for the services, so that to be able to make individual calculations depending on the services and the degree of their usage.

5.5 Informative instruments

Raising awareness and promoting public participation

In a large number of European countries, the local authorities launch education projects and awareness raising initiatives. Most local authorities have in employment a waste minimization officer, recycling officer or Agenda 21 officer. Many waste management companies also run a communication and public relations programme. Those campaigns aim either at generally raising awareness, or they aim at giving more detailed and specific information.

Another important issue in this context is public participation in projects prior to their realization, especially if these projects are likely to have an impact on people's lives. In most countries, environmental impacts assessments are required for a large number of infrastructure projects. One of the components in such assessments is that of establishing communication with the public. Here again, cultural differences influence the way in which the public communication takes place and which importance it is accorded in the decision-making process.

The European Week for Waste Reduction (www.ewwr.eu) is a pan-European initiative featuring multiple awareness raising actions addressed at businesses, schools, local authorities and associations. This broad campaign was launched in 2009 and is taking place in 25 countries in 2012 (20 in the EU).

In the United Kingdom, the campaign 'Are you doing your bit?' is an example of a nationwide awareness campaign. The publicity campaign was launched by the government to promote sustainable lifestyles. Simple environmental messages (for example on recycling) are broadcast through TV, press and radio advertisements in addition road shows and special events.

Improving of professional qualifications and training

It is of crucial importance to have an effective and competent workforce at all levels of waste management. Compared with other fields within the sector of civil engineering, waste management lacks a structured academic approach to get the required professional qualifications. During the last ten years, different environmental programmes were booming, with the issue of waste management forming part in varying degrees. In developing countries, there is also an acute problem caused by the lack of academic programmes to achieve diplomas in waste management subjects.

With regard to education and training, the International Solid Waste Association (ISWA) and its national members offer training courses on a range of waste management issues designed for different levels. Both national and international consultancies and other training providers offer different types of in-house training in environmental management for business and the industry. Many waste management companies have also taken up the challenge of internal education programmes, mostly as part of their quality and environmental management schemes. Today, such initiatives form an integral part of the social and ethic dimension of corporate policies.

In the era of new communication technologies, there are a large number of examples where Web-based resources are used to enhance training opportunities and to spread information and knowledge in the field of waste management. A number of universities are also offering distance-learning courses to provide training for those already employed in this sector. There is a need not only to prepare people entering the sector, but also to make people active in the sector evaluate their practical experience and to encourage them to go in for higher education.

Environmental reporting

Environmental reporting is a way of presenting the environmental effects of an activity in a clear and systematic manner. Environmental reporting is complementary to financial reporting and so far, only a few countries impose legal obligations to provide environmental reports. On the other hand, the market is pushing for those reports and companies in the waste industry are increasingly interested in demonstrating their environmental ambitions and achievements.

Research and technology transfer

There is a continuing need for research and technology transfer between countries. The exchange of experience can take place from industrialised countries to developing countries or between developing countries.

The R&D of solid waste management is often given low priority in developing countries. Handbooks and guidelines for developing countries which discuss the choice of waste management options need to be complemented with studies that take into consideration the appropriate management approaches and technologies, local climatic and physical conditions, the financial and human resources as well as social and cultural acceptability.

5.6 Legislation of the Republic of Uzbekistan regarding municipal solid waste management

The annual generation of industrial waste in Uzbekistan exceeds 100 mln tons, of which 14% is classified as toxic. The largest amount of waste is produced by the enterprises of mining and processing industries located in Navoiy, Tashkent and Fergana provinces. Only 0.2% of solid industrial wastes is used as secondary raw materials, while the rest is accumulated. Industrial waste accumulators take around 10 thousand hectars.

According to the State Committee for Nature Protection of Uzbekistan (2008), the annual generation of municipal waste is about 30 mln m^3. MSW includes household waste, wastes produced by different institutions (medical, educational, trade, business), by markets, street sweepings and a part of industrial waste stream class IV that are discharged at urban and rural landfills. Each million tons of MSW is discarded together with 360 thousand tons of food waste, 160 thousand tons of paper and cardboard, up to 55 thousand tons of textile, up to 45 thousand tons of plastic and other recyclable components.

Legal regulation in the sphere of MSW management is carried out in accordance with the framework laws of Uzbekistan:

- the Law on Nature Protection (1992);
- the Law on State Sanitary Control (1992);
- the Land Code of the Republic of Uzbekistan (1998);
- the Law on Wastes (2002).

The general legal foundation securing protection of national natural resources and efficient use of secondary materials is regulated by the resolutions of the Ministers' Cabinet:

- the resolution "On improving the regulation of import and export to and from the Republic of Uzbekistan of ozone-depleting substances and the produce containing them" (2005);
- the resolution "On the regulation of import and export to and from the Republic of Uzbekistan of environmentally hazardous produce and wastes" (2000);
- the resolution "On streamlining the work of enterprises regarding the use and disposal of mercury-containing lamps and appliances" (2000);

- the resolution “On improving the payment system for environmental pollution and disposal of wastes on the territory of the Republic of Uzbekistan”(2003), and other guiding and regulatory documents concerning waste management system.

Under the law of the Republic of Uzbekistan “On Wastes”, the governmental bodies authorized to control MSW management are:
- the State Committee for Nature Protection;
- the Ministry of Health;
- the agency “Uzkommunkhizmat”.

The agency “Uzkommunkhizmat” is responsible for developing and subjecting national MSW management programmes for approval in the duly order to the Cabinet of Ministers of the Republic of Uzbekistan; for monitoring collection, transporting, recycling and disposal systems state; for performing other duties in accordance with the legislation.

State cadaster of landfills and disposal facilities
The state cadaster of landfills and disposal facilities is run in accordance with the laws of the Republic of Uzbekistan “On Wastes”, “On State Cadasters” and other national legal acts.

The body authorized to keep the cadaster is the State Committee for Nature Protection. In 2007, there were 175 landfill and MSW disposal sites, 21 sludge accumulator, 4 ash-and-slag dumps, 22 tailing dumps and industrial waste landfills, 13 landfills for agricultural pesticides officially registered in the country.

The resolution of the government of Uzbekistan of 2014 set new “Regulations on the provision of services related to collection and transporting of municipal solid and liquid wastes collection and transporting”. The document describes the order of service provision, sets new requirements to the process, including compulsory primary sorting of MSW into separate disposable bags, which must be carried out by customers. It also regulates the order of payment for the services provided, the rights, responsibilities and liability of the customer and the executor.

The rates of MSW accumulation and their size per capita are determined according to the approved guidelines. This is a variable quantity which is to be periodically reviewed depending on the social and economic situation, the demographic changes and the development level of the serviced objects, but no less than once per five years. The rates of MSW accumulation for multi-family houses and detached houses are determined per capita per day depending on the facilities in the house (heating, gas supply, cold and hot water supply and sewage system).

Under the document "Sanitary regulations on collection, storage, transporting, disinfection and disposal of municipal solid waste (MSW) in the cities of the Republic of Uzbekistan" (1996), the average rate of MSW accumulation per capita is 1.2 kg per day or 453 kg per year.

Consumers are to fulfil primary sorting of municipal solid waste by categories into four separate disposable bags.

Chapter 6
Permits, Audits and Inspections

6.1 Application of Best Available Techniques (BAT) for waste treatment

The Directive on Integrated Pollution Prevention and Control (IPPC), adopted on 24 September 1996, introduced a relatively comprehensive approach to industrial regulation in the EU.

The IPPC Directive requires regulation of a wide range of industrial activities grouped into six categories: energy industries, production and processing of metals, mineral industries, chemical industries, waste management, and other activities such as pulp and paper, tanning, food processing and certain agricultural activities. From November 1999, European Union Member States must ensure that no new installation is operated and that no substantial change is made to the operation of an existing installation, without a permit.

In contrast to most end-of-pipe measures, pollution prevention promoted by the IPPC Directive is not only of environmental benefit, but its development and implementation is also helped by the fact that it often represents a significant cost benefit, because the generation of pollution and waste, including heat, reveals an inefficiency in the production process.

Special technical guidelines (BREFs) developed with the aim of implementing the requirements of the IPPC Directive contain a collection of information about modern techniques and equipment used, among others, in the area of waste treatment. These guidelines play a major role in informing the appropriate decision making officials about the best technical and economic solute ions for the increase of the nature protection indicators of industry.

For waste treatment two BREFs are relevant „Best Available Technique Reference Document" for Waste Incineration (WI-BREF) and document "Waste Treatments Industries", (WT-BREF) – installations for the disposal or recovery of hazardous waste with a capacity exceeding 10 tons per day.

The WT-BREF covers the activities described in IPPC-Directive, excluding waste incineration and some thermal waste treatments (covered by the WI-BREF) and waste landfills. Thus, the scope of this document focuses on the following:

- installations for the disposal of waste oils with a capacity exceeding 10 tons per day;
- installations for the disposal of non-hazardous waste with a capacity exceeding 50 tons per day.

The waste treatment activities covered by the WT-BREF document include common treatments, biological treatments, physical and chemical treatments, treatments to recover mainly the waste material and treatments to mainly produce fuel.

Mechanical biological treatment plants (MBT) are not specifically mentioned, but there are two sections dealing with the elements of MBT plants such as “biological treatments” and “waste treatments aimed to produce a material to be used as fuel”.

The abovementioned IPPC-Directive for the first time in world practice introduced the term «Best Available Techniques, (BAT)» on the legislation level.

Nowadays “the best available techniques” are treated as a modern instrument aimed at reducing the negative impact on the environment. The experience of European and other countries shows that the use of BAT allows using more ecologically and economically effective methods of technical regulation and rationing of the environmental pollution.

BAT is defined as follows: “best available techniques’ shall mean the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole.”

The issue of choosing the BAT is the key one when introducing technological rationing. The BAT selected for the integrated system of waste management has to meet the following main requirements:

- Propriety of the usage of this technique from the point of view of environmental protection, namely, the minimization of the anthropogenic impact on the environment;
- Correspondence of the technique to the latest innovations;
- Economic and practical acceptability of the chosen technique for the chosen community.

Overall, BAT used in the sphere of municipal waste processing can be divided into the following groups:

1. Preparation and extraction of the secondary raw materials:
   - mechanized component sorting of solid waste (glass, paper, plastic, wrapping);
   - biothermal aerobic composting;
   - anaerobic fermentation (biochemical fermentation of municipal solid waste);
2. Stabilization and preliminary processing of waste:
   - mechanical-biological treatment of waste;
   - drying waste using solar energy;
3. Thermal disposal of municipal solid waste:
   - burning;
   - gasification;
   - pyrolysis;
4. Landfill burying of municipal solid waste:
   - landfill-bioreactor (landfill with "mandatory" humidifying and irrigation);
   - landfill with aerobic stabilization of waste;
   - landfills with the degassing system;
   - landfill with the management of filtration waters;
   - landfill with aerobic and anaerobic stabilization of waste (semi-landfill).

The abovementioned technologies received a practical proof of the effectiveness of their application in different countries.

6.2 The Environmental Permits and Licensing

In order to obtain an Environmental Permit covering the IPPC requirements, full details of the installation and its mode of operation must be submitted to the appropriate authority. The proposed technology and/or techniques to prevent or failing this, reduce emissions from the installation must be detailed. The submission should outline the nature and quantities of foreseeable emissions to each medium and identify significant effects on the environment. Measures to prevent or recover waste from the installation must be detailed together with measures to monitor emissions to the environment. An environmental management system must be in operation to guarantee the operator's competence to maintain the requirements and conditions of the permit. The conditions of the permit may place Emission Limit Values (ELVs) on substances identified in the regulations as significant pollutants.

The determination of permit conditions under IPPC requires the regulator to take account of a number of principles in defining the desired operating conditions. These include the need for waste management practices as specified in the waste hierarchy (Waste Framework Directive) and principles of good environmental management, as promoted in the EMAS Regulation. They also include the principle of public access to environmental information elaborated by the Aarhus Convention and the concept of Best Available Techniques.

In general waste treatment facilities need a *permit*. This includes in general recovery and disposal operations along with preparation for recovery and disposal. Exemption for permitting can be made for recovery operations and for facilities that dispose of non-hazardous waste at the place of production. In this case, registration is required.

Registration is required for collectors and transporters of waste, for dealers and brokers. It is also required for the facilities exempted from the permitting system. At least the following information has to be included in the permit:

- types and quantities of waste that may be treated;
- technical and any other requirements relevant to the site concerned;
- the safety and precautionary measures to be taken;
- the method to be used for each type of operation;
- monitoring and control operations (as may be necessary);
- closure and after-care provisions (as may be necessary).

For *landfills* the following information is, at least, required within the permit: landfill class;

- list of defined types and total quantity of waste which are to be accepted as landfill
- requirements for the landfill preparations, landfilling operations and monitoring and control procedures (including contingency plans), provisional requirements for the closure and after-care operation);
- the obligation on the applicant to report at least annually to the competent authority on the types and quantities of waste disposed of and on the results of the monitoring program.

Permits can be combined with other permit requirements (national and EU legislation) to avoid duplication of information.

For most waste management operations, the permitting procedure is managed by *regional authorities*. However, for waste transfer, brokerage/dealing and reverse logistic operations, the responsibility mostly lies within *national authorities,* in most cases running a national register of such operations. *Local authorities* are also given responsibilities in the permitting procedures in many EU Member States.

Some former USSR countries (for instance, Russia, Belarus) require the obligatory *licensing* of the work and services connected with the impact on the environment in the waste treatment, namely, the use of waste of the 1-3 classes of hazard, disposal, and burying of waste.

The most important document submitted for the receipt of the special permit (license) to provide the right to carry out the activity that may affect the environment in the part of using the waste of the 1-3 classes of hazard, disposal, and burying of waste is the Technical Guideline.

The main licensing requirements and conditions to be met by the licensee include: special professional training for workers who are allowed to work with the wastes of the 1-3 classes of hazard, disposal, and burying of waste; operative management and use of equipment and instruments needed to carry out the work to use the waste of the 1-3 class of hazard, disposal, and burying of waste including the weight equipment when carrying out the burying of waste based on the right of ownership; carrying out of the local monitoring of the environment when disposing, and burying waste in the order established by law. The equipment for the utilization of waste has to be registered in a special register.

The licensing of preparing and processing secondary raw materials and waste containing precious and non-ferrous metals and precious stones is mandatory in the Republic of Uzbekistan. The legislation of the Republic of Uzbekistan does not require the licensing of the work with municipal solid waste.

The waste that is the object of purchase-sale, export-import operations along with the hazardous waste that must be transported have to undergo ecological certification to meet the requirements of sanitary norms and rules, and ecological standards in the area of waste treatment. The result of the certification allows issuing the ecological certificate to the owners of the waste.

For the purpose of collecting, processing, storing, and analyzing information about the places of burying and utilization of waste there is a State Cadastre for the burying places (landfills) and utilization of waste in Uzbekistan. This Cadastre contains quantity and quality characteristics of waste, information about waste treatment and measures to reduce their hazard degree.

6.3 Waste audit and inspection

A **waste audit** is a formal, structured process used to quantify the amount and types of waste being generated by an organization. Information from audits will help identify current waste practices and how they can be improved. Being waste-wise can mean:

- a more efficient and effective organization;
- reduced waste management costs;
- better use of limited natural resources.

Audits can be done on any type of waste, e.g. paper and office waste, municipal waste, commercial and industrial waste, construction and demolition waste, etc. There are a number of different ways to conduct a waste audit, such as visual waste audits, waste characterization, desktop audits and others. The type of audit you use depends on the type of waste, where it is and what you want to get out of the audit.

The audit's objectives will largely determine the waste types and physical locations to be audited. Some examples of audit objectives could be:

- to determine composition and quantities of waste being generated;
- to measure effectiveness of existing waste management systems;
- to identify opportunities for improving waste management systems and strategies;
- to collect baseline data for measuring the effectiveness of waste minimisation strategies.

Auditing of waste is a relatively simple process but can be fiddly. The following basic steps to doing an audit can be provided (table 6.1).

A waste audit is an analysis of waste stream. It can identify what types of recyclable materials and waste your office generates and how much of each type is recovered for recycling or discarded. Using the data collected during a waste audit, organization can identify ways to reduce waste and enhance its recycling efforts and determine the potential for cost savings. By designing a more efficient waste disposal program, business can increase the amount of paper, plastic, and metals that it recycles, which reduces air and water pollution, helps curb global warming, and conserves natural resources.

Recycling and composting can save money through avoided disposal and hauling costs. Many recyclable items can also be sold on the market as a source of revenue. A waste audit can help company identify these potential savings and revenue opportunities.

During a waste audit, the auditor investigates the sources, composition, weight, volume, and destinations of the waste that your business generates. Some government or not-for-profit organizations will perform this service free of charge, or it can be done in-house. By learning more about the trash municipality/company generates, people can be better informed about the products they buy that

Table 6.1 Example of waste auditing process

Stage	Aim	Actions
PLAN	Define the study area	Set audit objectives Determine location(s) to be audited Determine types and approximate quantities of waste to be audited
	Collect background information	Visit location(s) and record: • number of employees in study area • number, types and locations of bins • types of waste seen • who empties bins and when
	Prepare for the audit	Collect auditing equipment Brief/train cleaners and sorters Finalize waste collection details Double-check locations of bins
COLLECT	Collect the waste	Collect all waste daily Label bags showing location and day Record relevant collection details
	Transport the waste to the sorting area	Store waste on-site if possible Otherwise transport to secure location using a licensed transporter
SORT	Prepare the sorting area	Cover tables with plastic Set up tables and scales Collect buckets, bins, brooms, etc. Have water and first aid kit on hand
	Sort the waste	Weigh each bag/bin Carefully open bag/bin and spread waste on table Sort into different material categories Count and weigh individual materials Record findings on data sheet Dispose of sorted waste Repeat for all bags/bins
	Final clean up and decontamination	Dispose of sorted waste Clean off tables Clean buckets and other equipment Sweep and disinfect floor Shower and change clothes
ANALYSE	Enter and analyze the data	Enter data sheets onto spreadsheet Do calculations
	Prepare an audit report	Prepare audit report, including findings and recommendations

contribute to waste and be better prepared to more efficiently dispose of it, saving money and improving municipality/company's environmental performance.

Performing a waste audit is an effective way to learn more about the trash your business generates. In order to create an accurate representation of your waste stream and recycling efforts, consider performing multiple waste audits at different seasons during the year.

Figure 6.1 Performing of waste audit

The European Waste Framework Directive (WFD) sets obligations for inspections. Following this provision, establishments or undertakings which carry out waste treatment operations, establishments or undertakings, which collect or transport waste on a professional basis, brokers and dealers, and establishments or undertakings which produce hazardous waste shall be subject to appropriate periodic inspections by the competent authorities.

The WFD stipulates that inspections concerning collection and transport operations shall cover the origin, nature, quantity and destination of the waste collected and transported. According WFD, EU Member States may take account of registrations obtained during the Community Eco-Management and Audit Scheme (EMAS) of ISO 14001, in particular regarding the frequency and intensity of inspections.

Traditional inspection activities are the (physical) routine (site) inspections, non-routine (site) inspections and investigations of incidents. Many of these activities can and should be executed according to guides, standard protocols and working instructions.

6.4 Waste management and Environmental Management System (EMS)

We should clearly differentiate between the audit of the flows themselves and the composition of the waste that is usually decided on by the organization that works with waste management and the audit of the organization itself. In the latter case, the audit can be carried out following the scheme defined by the particular management system used in the organization (quality, environment, health and safety). This scheme is most frequently realized in the form of the evaluation in terms of meeting the requirements of the standards ISO 9001, or ISO 14001, or ISO 18001, or EMAS.

Waste Management is committed to ensuring advanced protection of the environment, compliance with governmental regulations and implementation of state-of-the-art technology. These efforts distinguish Waste Management as the foremost leader in environmental protection and solid waste management excellence. The Environmental Management System reflects the Company's emphasis on continuous improvement in operations by measuring and evaluating its environmental performance.

Waste Management's EMS is comprised of five integrated components including:

- Policy;
- Planning;
- Implementation;
- Assessment and Corrective Action;
- Management Review Processes.

EMS can be an excellent tool for achieving meaningful environmental improvements, safer and healthier workplaces, and improved competitiveness. An EMS is a formal set of procedures and policies that defines how an organization will evaluate, manage, and track its environmental impacts. ISO 14001 is the international EMS standard.

Most organizations build their EMS on the circular "Plan, Do, Check, Act" model and take the following key actions:

- Draft a policy statement proclaiming the organization's commitment to the environment;
- Identify significant impacts of products, activities, and services;
- Develop environmental objectives and goals for the organization;
- Implement plans to meet the objectives and goals;
- Train employees about their environmental responsibilities;
- Perform periodic management reviews of the system to ensure that it is constantly adapting to new needs.

Chapter 7
Waste Collection, Handling and Storage (SD)

Reducing the negative environmental impact of waste management requires optimizing the interaction between different elements of waste management system. Besides, account should be taken not only of the ecological aspects, but also of the economic, technological, organizational and social ones.

7.1 Collection of municipal solid waste (MSW)

The method of collecting MSW determines the choice of waste recycling methods (see fig.7.1). For mixed waste the most acceptable recycling methods, from the technological and economic points of view, are incineration and landfilling. But incineration of mixed waste produces toxic air emissions and toxic ash that require costly treatment and recycling. Landfilling mixed waste results in toxic filtrate and landfill gas production due to the decomposition of MSW, on the one hand, and in an irretrievable loss of useful resources contained in the waste, on the other.

Waste separation at source or sorting mixed waste will make it possible to use recyclable fractions of MSW for energy recovery or manufacturing of usable products.

The process of waste collection comprises activities from providing and filling waste containers to waste removal by a garbage truck or emptying waste containers. Consequently, waste collection system is a combination of human activities and technical measures and processes which is characterized by:

- waste containers;
- ways of providing and emptying waste containers;
- garbage trucks.

In communities with various types of dwelling buildings and enterprises it is almost impossible to use one system for collecting all types of waste efficiently. That is why there should be several different collection systems, tailored to the quantity and quality of waste, the territorial conditions and other local requirements.

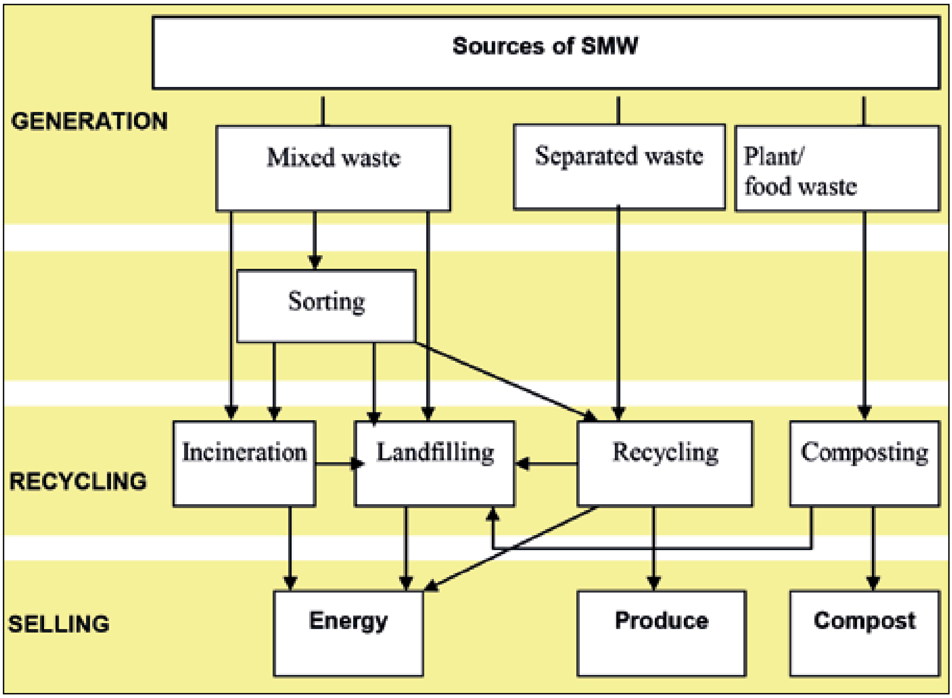

Figure 7.1 Waste movement from the source to the final recycling point.

The bulk of expenses for the MSW management system is associated with waste collection. From the wide range of waste collection methods, the most frequently used are centralized collection of waste left on the curbside and self-delivery of waste. These methods can be used both separately and jointly.

The centralized system of collecting waste from the curbside (the so-called door-to-door waste collection system) is the simplest scheme employed in many countries both for mixed and separated waste. With this system, waste is left on the curbside in a plastic bag or a bucket or put inside a container that may be permanently located in a special place or driven outside at a definite time. Then waste is picked up by a special vehicle (garbage truck).

In this MSW collection system, waste generator is responsible for timely positioning of waste on the curb on the collection day and removal of containers after waste has been collected by the utilities.

The centralized system of collecting waste from the curbside is frequently employed in the private sector, as well as the multistorey dwelling areas (whether having refuse chutes or not). This system is used for collecting both mixed and separated waste.

Figure 7.2 Door-to-door waste collection system in Uppsala, Sweden. The householder has left two mobile containers on the curb. One container is filled with waste to be sent to the incineration plant, the other contains biodegradable waste to be used for composting or producing biogas.

Figure 7.3 Special waste collection station in Jonköping (Sweden) created by the waste collection company SITA. Residents independently deliver car batteries, collected waste oil, packaging from paintwork materials, fluorescent and other bulbs, bulky waste, etc.

While collecting separated waste, to avoid mixing of different fractions it is desirable to use specially coloured containers. For example, using grey containers for mixed waste, green containers for paper, brown ones for biodegradable waste, red ones for hazardous waste (e.g., batteries), etc.

Self-delivery of waste means that residents deliver waste to special waste collection facilities. In this case, the distance of waste transportation from the collection facility to the recycling facility decreases for garbage trucks, but increases for waste generators.

Centralized MSW collection facilities can be located in a separate building or on the open territory either roofed or not. From these facilities waste is removed at periods determined according to the containers' capacity and the decomposition time of some waste fractions (plant and food waste).

As a rule, centralized MSW collection facilities are organized for the waste types that are not within municipalities' responsibility. For example, "waste stations" created by waste management companies in Sweden and Germany allow residents to independently deliver and sort waste into 15-20 categories.

Figure 7.4 Deposit waste collection system in work. Empty bottle collection site in a supermarket in Sweden.

Waste self-delivery system includes the so-called deposit (barter) collection system for definite categories of waste. This system embraces waste left after using products the price of which included a *deposit*. These can be various types of tare (plastic, glass, etc.), household devices (thermometers, mercury bulbs, etc.) and other goods.

In the barter collection system, consumers return waste to special collection facilities to get back the money paid for the product.

As a rule, the barter collection system is regulated by legal acts that determine the sum of the deposit and oblige collection facilities to take waste from the population and pay the money back. This system generally encourages a high waste collection level.

7.2 Waste separation and sorting

SMW can be sorted by households or at the sorting stations. The choice of sorting scheme depends on the expenses on waste sorting and collection, the cost of recovered resources, the legal requirements and the existing waste recovery infrastructure. Traditionally, sorting is performed for the following fractions of waste:

- organic waste, since their presence hinders the recovery of resources;
- wastes that are legally required to be collected and recycled separately;
- recoverable material resources.

For mixed waste sorting is always preferable. It is usually performed mechanically by means of special equipment and aims at changing physical properties of

Figure 7.5 Semiautomatic paper sorting station (17 fractions)

waste, removal of certain components and contaminants and preparing separate fractions to further processing (recycling, incineration, biological treatment) or landfilling.

Complex sorting of waste includes the processes of separate collection at source (for example, separation of the whole waste flow into "wet" and "dry" wastes; or separation into several fractions, etc.), recoverable resources collection facilities and waste collection plants (complexes). At these plants specially trained staff or automatic sorting systems sort waste by size and materials. Then recoverable waste is grinded, packed and sent to recovery.

Mechanical centralized sorting is usually performed to sort unseparated waste and to redo the sorting of waste in order to improve the quality of solid waste as a recoverable resource.

However, industrial experience shows that the quality of mechanically sorted fractions, except for metals, proves lower than manually sorted ones.

The main process used for extracting waste paper (and also for separating SMW into two fractions: the heavy and the light ones) is air separation. Ferrous metals having strong magnetic properties are extracted by magnetic separation. Non-ferrous metals are extracted by electrodynamic separation, as well as by flotation and gravitation. To detach polymer film from paper electric separation in performed. Special methods are designed for separating textile components, for extracting magnetic concentrate from tin-bearing components, etc.

The number of separating operations, their type and sequence order depend on the morphological and grain-size composition of waste and its humidity, as well as the aim of sorting in each case and the mechanisms of resources separation.

An important issue to be solved for the sorting to be successful is the location of the sorting complex. One of the conditions of successful sorting is minimal compactness of waste to be sorted. Taking this into account and the fact that transporting mixed noncompacted waste to large distances entails considerable expenses, it is desirable to build sorting stations as close to waste generation sources as possible. But in this case the construction is opposed by the local residents who regard waste sorting stations as sources of bad smells, noise and insanitation. For this reason, sorting stations are usually organized near MSW landfills, which also allow to compact sorting remains to be landfilled.

Waste sorting plants (complexes) perform mechanical sorting, but it is usually ended manually (like additional sorting). Entirely manual sorting results in a higher quality of fractions, but the productivity of this method is much lower.

On the other hand, the construction and operation of mechanical sorting lines entail considerable investments. The final choice of the degree of waste sorting mechanization depends on the labour-intensiveness of the process and the cost of manual labour, the choice of technologies and further treatment methods.

Waste sorting performed by the households. Waste sorting at source or their separate collection id the most efficient method to separate waste into fractions.

The advantages of separate collection of MSW are lower sorting costs and getting relatively clean (homogeneous) fractions. The disadvantage of this scheme is the necessity to create a suitable (convenient and efficient) infrastructure for separate collection of waste fractions by the population, and to maintain continuous interaction with the population.

To collect separate fractions households should have special tare with several chambers or plastic bags for different fractions of waste. The expenses for purchasing this tare are usually borne by the population.

In general, the efficiency of MSW sorting performed by the population depends on the level of awareness, convenience and motivation.

Convenience. An improperly organized infrastructure for separate collection of MSW will result in the necessity to additionally sort the collected fractions, which in turn will increase the expenditures. In cases when implementing a differentiated fee for the disposal of unseparated SMW presents difficulties (e.g. in multistorey buildings with refuse chutes), convenience will be the decisive factor for the population to start separate collection of waste.

Awareness. Clearly and consistently informing the population on the necessity to sort waste must be the main line of a long-term waste management strategy. Even the role of school education should not be disregarded, since children generally give a big hand in sorting waste at home. To facilitate the process of sorting, it is necessary to continually inform the population on the existing waste flows, the fractions extracted and the recovery methods for each fraction.

Motivation. It may be principally stimulated by the floating rate (differentiated fee) for collecting and recycling MSW. The approach is generally based on decreasing the fee for the total amount of waste minus the sorted waste.

The system of separate collection of MSW will not be efficient if:

- the population is poorly informed on the issues of waste collection, the location of containers, the schedule of waste removing, etc.
- containers have inadequate capacity or are not sufficient in number;
- special vehicles used for transporting MSW are not appropriate for the purpose or have inadequate capacity;
- the routes of transporting waste are poorly planned.

Waste sorting problems. In the Eastern European and Central Asian countries the system of separate collection of waste and its recovery is not developed yet. To make waste recycling a profitable business, it is necessary to solve certain problems associated with waste sorting:

To provide containers for separate collection of waste. Just placing differently coloured containers in the yards is not enough. It is necessary to put on them or right near them posters containing information on what types of waste can be discharged into each of the containers and how it should be done. For example, plastic bottles placed in a corresponding container should be compressed and devoid of lids, since it will spare the sorting plant's staff the necessity to remove lids from each bottle prior to compressing them. Besides, a garbage truck can hold more bottles if they are compressed, and the utility employees will not transport air.

To inform the population on the advantages of separate collection of waste by publications in mass-media. It is also necessary to control separate collection of waste and reward them for doing this. Besides, the population should be clearly informed on how to separate waste and where to discharge each of the fractions.

To build specialized waste sorting plants (complexes), responsible for further sorting of waste collected from the population. It would help to sort household waste more thoroughly, which in turn would benefit the quality of waste recovery.

7.3 Waste transportation

Collected waste should be transported to the corresponding treatment and decontamination facilities. This may require long- and short-distance haulage. There is a tendency to locate waste treatment facilities in the central areas, which results in the growing importance of long-distance haulage and transfer of wastes.

Box 7.1 Waste sorting rules

may vary significantly depending on the country, especially in what concerns the colours of containers for different waste categories, but still they have more in common than differences.

The general sorting rules:

- All food waste, just as other organic waste like grass or foliage, as well as paper napkins and towels, must be collected together.
- Glass must be placed in a separate container.
- Paper and cardboard must be separated from all other waste.
- Plastic and metal packaging is recoverable and therefore must be collected in a separate container.
- Batteries, mercury bulbs and other environmentally hazardous objects must be collected separately.
- Non-recoverable waste should be placed in a separate container, too.

Long-distance haulage is particularly required when the proper waste treatment facilities are located at a distance, while other treatment methods are excluded for reasons of economy. Various vehicles with suitable container systems can be used for this purpose. In some cases waste transfer will be performed at transfer stations.

Vehicles. The choice of vehicles for waste collection and transportation depends on the category of waste and the conditions of collection. Garbage trucks differ by the type of chassis, the truck body design, the types of compression device and lifting mechanism.

A vehicle may have a double axle chassis (such construction is more maneuverable and suitable for town use) or a three axle one (more appropriate for the rural area). The volume of a truck's container may vary from 5 m^3 to 23 m^3.

Presses and rotary drums can be used as compression devices. In a rotary drum a rotating screw compacts waste by pushing it towards the back of the container. Such compaction method is best applicable for organic fractions, since they are easily compacted and blended during this process. Drums should not be used on the trucks collecting waste to be sorted; instead plates should be employed.

Weight lifting mechanisms can be either manually or mechanically operated, located either on the front or the back side of the truck. They differ depending on the type of waste containers they are designed for, i.e. they can be round, square, two- or four-wheeled, etc. Waste lifting mechanisms are usually designed to raise 360-1,100 litres containers.

The standardization of waste containers makes it possible to reduce the range of lifting mechanisms. An important parameter for the efficiency of waste collection and reduction of expenses is the time required for lifting and loading waste containers. The truck's capacity is of importance too, since it influences fuel consumption. Using a lifting device with a high hoisting capacity (e.g. 3,000-5,000 litres) is uneconomic when the containers to be lifted are small (smaller than 1,000 litres).

Back-loaded trucks are the most frequent type of a standard vehicle used for collecting waste. They can be equipped with different special loading mechanisms. These trucks are used for waste collection and short-distance haulage in different conditions. Waste is loaded into the loading buckets by the lifting mechanism. Then it is compacted by the press and fed into the truck's body. When the body is filled, the waste truck drives to a landfill or a waste treatment facility and unloaded from the front side. Such garbage trucks are rather universal and easy to park. Their principal disadvantage is that they require a driver and minimum one worker (loader) to operate efficiently.

Front-loaded trucks (waste loading is performed from the top) are more suitable for large capacity containers used in populous areas. Besides, the work can be done by one person. But these trucks have more constraints as to their speed and maneuverability.

Vehicles with side traverse mast have the same advantages as front-loaded trucks. Such trucks are most suitable for suburbs and rural areas. Garbage trucks with side traverse mast can collect waste from a thousand of containers with 60-1,100 litres capacity per day. The main disadvantage of this vehicle as compared to the front-loaded and the back-loaded trucks is their high price (duy to the advanced methods allowing just one person to operate the truck). Besides, they are not as universal as the front-loaded trucks.

Factors influencing waste transportation costs. Waste transportation requires considerable expenditures depending to a large degree on the distance of haulage and the number of stops to collect waste.

MSW transportation cost is determined by the waste density, moisture content and the coefficient of compactness, since all of these factors influence the size and design of the vehicle to be used.

The location of waste collection sites and the frequency of collections determine the choice of garbage trucks, too. Some streets and lanes can be inaccessible for certain vehicles because of their width, slope, road surface, traffic intensity, etc. The frequency of collection depends primarily on the physical properties of waste and its average daily amount. In most cases the frequency is fixed and is determined by the municipality based on the town utilities' working hours.

Front-loaded waste truck

Side-loaded waste truck

Back-loaded truck (two-section)

Back-loaded truck (one-section)

Mounting a shipping container for waste on a truck's chassis

Transfer of a removable container for waste

Figure 7.6 Garbage trucks and container trucks with different loading types

7.4 Waste transfer stations

Waste transfer is practical when waste treatment and decontamination facilities are located at a distance so far that the total cost of transporting them by waste collecting trucks exceeds the cost of construction a transfer station and further transportation by a long-haulage vehicle. Transfer stations should be located in the centre of the territory from which waste is collected. They should also have haulways.

Transfer stations combine the technical processes and the place for transferring waste from garbage collecting trucks to long-haulage vehicles (trucks, railway, ships). In some cases the waste to be transferred undergoes prior sorting and compressing.

Transfer stations are an important component of the waste management system contributing to the optimization of the waste recycling process and minimization of transportation costs. Transfer stations save time and spare the necessity to use specialized garbage collecting trucks for long-distance haulages. Transfer stations should be located as close to waste generation sources as possible and have transport connections.

In its simplest configuration, a transfer station is a site with hard surface where swap-bodies of garbage trucks are transferred to long-distance haulers. There are different types of swap-bodies that can be transferred without special equipment or by means of special cranes, loading ramps, etc.

Garbage trucks that do not have swap-bodies should be first unloaded at a transfer station. The same concerns swap-body trucks if their bodies cannot be transferred to the long-distance hauler. Unloading may be performed on the site by means of wheeled loaders, conveyor belts and excavators. Another option is to transfer waste on the loading ramp straight from a garbage truck to a long-distance hauler, an open container or an intake of a press.

Presented below (fig.7.7) are some examples of transfer stations, where waste is unloaded from garbage trucks.

At transfer stations waste is usually stored in flat-rack containers. Right at the transfer station garbage trucks parked on the ramp can unload waste into trucks with higher capacity, equipped with waste compacting mechanisms. This process requires less manual labour and little stationary equipment. Besides, it allows to quickly transfer waste simultaneously compacting it to 400-500 kg/m^2.

At a rail or water transfer stations the same technology is used except that such stations need access to water or rail ways. The same requirement applies

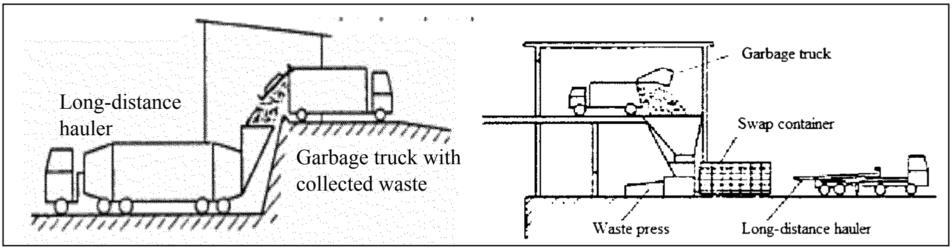

Figure 7.7 Different types of transfer stations

destination points. Rail and water transport is practical for large volumes of transported waste, since it is more economic. But it has considerable logistic and economic restrictions and therefore is rarely used for waste transportation.

Intermodal truck-to-rail containers can be used for long-distance railroad fright without any special technical devices.

Chapter 8
Types and Technologies of Waste Treatment

8.1 Mechanical biological treatment of waste

A **mechanical biological treatment** (MBT) system is a type of waste processing facility that combines a sorting facility with a form of biological treatment such as composting or anaerobic digestion. MBT plants are designed to process mixed household waste as well as commercial and industrial wastes.

The mechanical biological treatment is used to process mixed waste with a high content of organic elements and carbon. The goal of this kind of processing is the following:

- to stabilize waste and significantly reduce the mass and volume of waste due to its biological biodegradability (thereby reducing the percentage of biologically active waste sent for disposal);
- to separate waste into different material flows, to select materials for utilization, and to improve the properties of waste prior to its submission to further processing stages.

The residual mixed waste is processed by various mechanical and biological means upon the mechanical biological treatment. Consequently, this decreases its reactivity as well as the potential forming of harmful substances allowing storing them safely. Moreover, the combination of different processing means helps to reduce the volume of waste, to obtain materials suitable for further use and, in some cases, to produce energy.

Due to their high flexibility MBT technologies can be easily modified to adapt to the changing composition of waste while increasing plant capacity. There is no need to introduce strict requirements for waste collection as there is no need for pre-separation of household waste when using this processing method.

The main technologies of biological treatment include anaerobic fermentation, composting or separate elements of both technologies.

The main MBT drawbacks include the incomplete mineralization of waste that requires additional treatment while landfills need subsequent control.

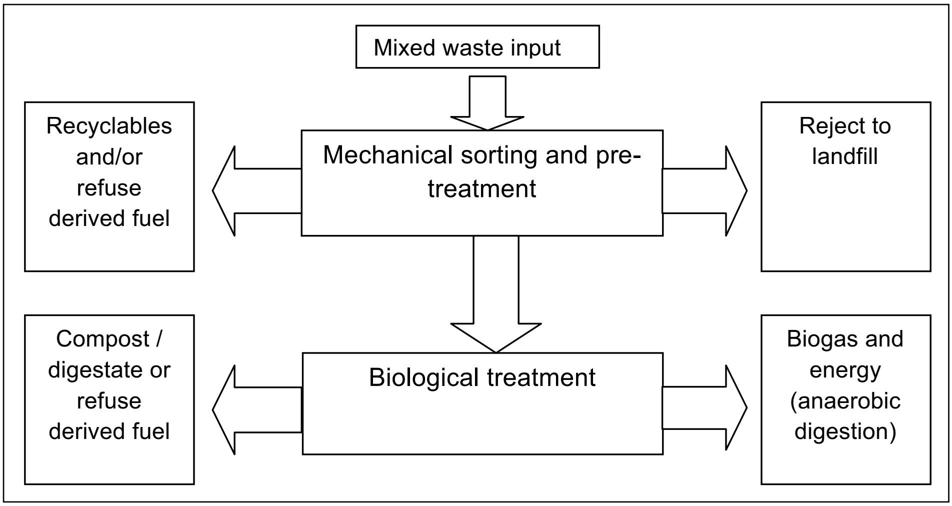

Figure 8.1. Diagram of mechanical biological treatment of waste

The mechanical biological treatment can be used for all kinds of waste which require a reduction of their biological activity in the place of storage. However, this reduces the costs of further control. To a great extent, this type of treatment encourages a sustainable exploitation of landfills and reduces their harmful effect on the environment. Studies of the environmental consequences show that the placing of stabilized waste for storage leads to the emission of only 10% of biogas and 10% of filtrated water in comparison with untreated waste.

Recently the technology of the mechanical biological treatment in Europe has reached a high technical level. At present there are quite many plants in Europe that treat municipal solid waste (MSW) using the described technology. The average capacity of such plants reaches 100,000 tons/year though there are plants with the capacity of up to 300,000 tons per year.

8.2 Fermentation, drying and thermal treatment

Another biological method of industrial processing of municipal solid waste is the extraction and utilization of biogas formed during the anaerobic decomposition of organic elements of MSW. European countries (for instance, Germany and Sweden) widely use the technology of receiving biogas from the biological fraction extracted from MSW upon its enrichment at special plants. The possibility of carrying out anaerobic fermentation of the MSW organic fraction should be considered when there is a practical need for biogas (in view of its low quality). Anaerobic decomposition is generally used for mixed kinds of waste by combining household waste and other kinds of corresponding waste.

Those operations which are used to treat waste and which are based on the principle of anaerobic fermentation should be regarded as a supplement of composting but they differ due to the production of biogas and as a rule, require less space. There are also usually fewer restrictions for the initial material. Anaerobic digestion can thus be used as an independent process for the treatment of biological but initially separately collected waste though it can also be an integral part of the mechanical biological treatment of residual mixed waste.

The anoxic or anaerobic technology for the processing of biological mass uses different bacterial groups which gradually decompose high molecular organic compounds into simple end products, namely, methane and carbon dioxide in a three-stage process (hydrolysis, fermentation and methane production).

The final product is biogas which is the source of energy. Recently its popularity has grown considerably in the countries of the European Union due to the proliferation of use of the alternative sources of energy. Biogas is composed mainly of methane (CH_4) and carbon dioxide (CO_2). Depending on the quality of raw materials and processing technology the content of methane in biogas varies from 55 to 75% though in certain cases it can even reach up to 95%. Other essential components of biogas are carbon dioxide (30-40%), hydrogen (5-10%), nitrogen (1-2%), and hydrogen sulfide (< 1%).

The production of biogas in the anaerobic process takes place in an oxygen free environment, thus, requiring a closed reservoir for the production process. This container is a specially designed reactor or isolated power cells at the waste landfill. The production of biogas at the industrial level requires a complex production facility that consists of the system of biomass accumulation, the biomass reactor (processing equipment) and the system of biogas storage and purification.

The advantages of anaerobic technologies include the ability to produce biogas and use the residual decomposition products as a fertilizer. The drawbacks are high demands on the quality of raw materials; the waste should not contain any impurities and contaminants; the costs of the processes of anaerobic decomposition connected with the need to use a great number of reactors of high capacity are high.

The drying of waste with the use of solar energy is often used to reduce the volume and increase the heating capacity of the sludge sewage water and waste with a high content of water and biogenic components. The drying is often carried out in workshops with a transparent roof. The waste is heated by the energy of solar radiation while the atmosphere in the workshop allows the moisture move into the air. To increase the drying efficiency the waste is hoed and stirred up. The drying with the use of solar energy is often accompanied by the use of heating systems. As a rule, the units operate in a batch drying mode. The input material is the liquid residue with the dry substance content of 1-10%; the dewatered sludge with the dry substance content of 10-40% (typically, more than 20%). The output of the dry content is 50-90%; there are almost no losses from biological decomposition.

Thermal methods of waste treatment are among the most common means of waste processing and, depending on the conditions of the process, include oxidation, decomposition and regeneration of chemical compounds that make up waste.

Very often these processes occur simultaneously during the waste heating. The main purpose of this treatment is the disposal of waste and the reduction of waste volume but in addition to this a number of thermal treatment methods allow to get valuable goods from waste.

Thermal methods include:

- liquid phase oxidation,
- heterogeneous catalysis,
- gasification and pyrolysis of waste,
- plasma and fire methods.

Incineration is a popular method of thermal waste treatment. It is implemented at the temperature of not lower than 600°C and relates to the thermal oxidative processes of autogenic character. Autogenic means that the heat produced during oxidation is sufficient to support combustion and that no additional fuel is required. On the whole, in can be assumed that the volume of waste is reduced by 90% and the weight by 75% as a result of complete combustion of household waste rich in organic elements. Assuming that the initial volume of waste substances is 100%, then its volume after combustion for organic liquids is 0,1-0,2%; for organic solid substances is 2,0-5,0%; and for municipal solid waste is 5,0-15,0%.

As a method of treatment incineration is used for partially sorted waste which contains no more than 10-15% of non-combustible material. To burn, one should use organic waste with a high calorific value. The combustion of the organic part of waste generates dioxide and carbon monoxide, water vapor, nitrogen and sulfur oxides and aerosols. The scope of use of thermal methods is limited by the properties of reaction products. They can’t be used for the treatment of waste if the latter contains phosphorus, halogens, sulfur. In this case the combustion reaction products can form, for instance, secondary highly toxic substances (polychlo-

Figure 8.2 Incineration plant in Uppsala – one of many such plants operating in Sweden. This plant produces electricity and heat for the city and county with the population of about 500 thousand people. Environmental protection measures are the primary concern at the plant. Photo: Vattenfall.

rinated biphenyls – PCBs, dioxins and furans) which are together with heavy metals and with smoke gases, waste water and slag is emitted into the environment.

Along with the cleaning of flue gases the challenge for the plants is the utilization and disposal of toxic ash and slag remaining after incineration (up to 30 % of the MSW dry weight). The concentration of heavy metal oxides is 2-3 order higher in them than in the incinerated waste.

Municipal solid waste can be incinerated at various plants including plants with grate and rotary kilns and with a fluidized bed.

The main useful product of waste incineration is usually the heat of exhaust gases used as secondary energy sources to produce steam, electricity, and hot water for industrial and domestic needs. Table 8.1 presents advantages and drawbacks of the incineration method for waste disposal.

Gasification as an industrial technology is used for the treatment of solid, liquid and paste like waste.

Gasification is the treatment of carbonaceous material at 600-1,100 °C with steam, oxygen (air) and carbon dioxide. An equilibrium mixture of newly formed (hydrogen, carbon monoxide) and source gases is formed as a result of steam,

Table 8.1 Advantages and drawbacks of incineration

Advantages	Drawbacks
1. It allows to get rid of large amounts of waste simultaneously	1. The reduction of exhaust gas emission by improving their washing and cleaning does not lead to the reduction of the amount of toxic residual materials but rather transforms them into ashes and creates problems of safe disposal of toxic ash and pollution of waste water
2. It is convenient in large cities and large enterprises because it allows to get rid of waste once it appears	2. When using municipal waste incineration plants and installations for thermal processing of waste it is very difficult to provide a uniform flow of materials with a standard calorific value. The composition of waste including waste calorific value and moisture content is constantly changing. As a result, it is difficult to maintain constant conditions of incineration needed to minimize the toxicity of emissions in these installations.
3. Reduction of waste volume by 90-95%	3. Waste incineration leads to the production of highly toxic ash which later has to be disposed of as well using one of the abovementioned methods
4. Use of thermal energy, production of electricity	4. It is difficult to control the getting of forbidden toxic waste or such materials as polyvinyl chloride to the thermal treatment equipment; such materials can produce a large amount of dioxin upon incineration
	5. Expensive gas purification procedure worsens the economic indicators of such plants

oxygen, carbon dioxide or combined substance conversion. This mixture (product gas, syngas) comprising the product of incomplete oxidation of coal (carbon monoxide) and hydrogen has a redox potential and is used as a gaseous fuel. The synthesis gas may contain a mist of liquid resinous substances but its redox potential almost excludes the presence of sulfur and nitrogen oxides.

Pyrolysis, as a method of heating organic substances to relatively high temperatures without access to air is accompanied by the decomposition of high molecular compounds into low molecular compounds, liquid and gaseous fractions, as well as coking and gum formation. It is used in the dry distillation of wood waste, processing of rubber goods, petroleum products, etc.

Drawbacks of thermal methods to a certain extent are eliminated through the organization of separate collection of waste in the places where waste forms. This separate collection does not cover only such valuable waste as glass, metal, waste paper, etc. but also hazardous waste (waste of dry galvanic elements and used mercury lamps, etc). Modern waste incineration plants that use the prepared waste that has gone through a thorough sorting process as fuel and which are equipped with an effective modern multistage cleaning system for exhaust gases and thermal equipment are no longer just a safe element of the system of waste removal. Such plants have also become one of the alternative sources of energy that corresponds to the requirements of resource saving. The actual absence of the separate collection of waste and a long time needed to create an effective system of selective collection associated with a low level of ecological conscience of people lead to a significant limitation of the possibility to use thermal technologies for direct incineration of non-prepared waste.

8.3 Composting

Composting is an aerobic method of processing during which and under optimal conditions of air and humidity organic substances are transformed into a humus like product, namely, compost. It is produced as a result of partial decomposition of certain products which contain some organic matter and non-organic ballast substances. It is used in agriculture, horticulture, and in the forming of landscapes. The diagram of the compost production process is shown on Figure 8.3.

The composting process consists of four phases:

- the heating phase;
- the aeration phase;
- the structuring phase;
- the compost extract.

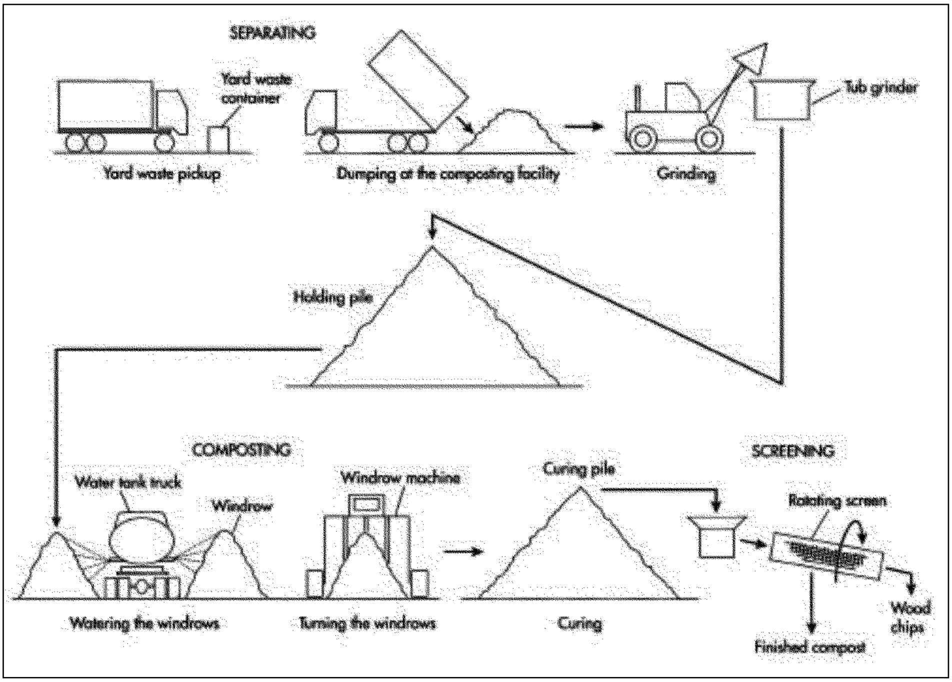

Figure 8.3 Diagram of the composting process

Figure 8.4 Processing of compost in the landfill in the town of Uppsala, Sweden

Composting is carried out either in an open pit or in closed bioreactors. The open pit composting presupposes the use of open pits (trenches) or static or aerated piles. The latter are the most common. This technology allows forming trapezoidal piles of 1,5-2 meters high onto which raw material of compost is stacked (crushed and mixed waste) and which are placed in the direction of ruling winds. They are periodically mixed to provide optimum conditions of air and humidity. The control of temperature upon the optimal process ensures a more effective destruction of pathogens and a faster decomposition of compost mass, even in 3-4 months.

Closed type bioreactors can be used to accelerate the process of composting and provide the optimum operation of the process. In bioreactors the waste is mixed and the air is supplied additionally in order to speed up the decomposition process. Optimum decomposition parameters are maintained throughout the recycling processing. They include a certain level of humidity, temperature, the amount of oxygen, pH, the amount of phosphorus and nitrogen. Specific ratios of C:N, C:P и C:H have to be maintained as well. The provision of these conditions allows obtaining high quality compost within a very short period of time reducing the composting period to a few weeks.

The processing of organic solid waste into compost is a perfect method of its neutralizing and further use. The main advantages of composting methods in the treatment of waste include the return of the waste plant nutrients back into the turnover of the ecosystem; the reduction of the amount of stored biologically degradable waste components; the simultaneous fruitful use of other organic waste products in compost (leaves, grass, manure, municipal waste water sludge, etc.). However, the total share of waste treated by composting remains quite small. For instance, only 2% of waste is treated in order to receive compost in Europe. A number of compost plants were built in the CIS countries but almost all of them produce compost of low quality. The main shortcoming of this method is that the waste does not go through the proper initial processing and the final product may contain combinations of heavy metals and chemically hazardous elements.

Chapter 9
Management of Municipal Solid Waste

9.1 Elements of waste management system

A comprehensive municipal solid waste management (MSWM) system includes some or all of the following activities:

- setting policies;
- developing and enforcing regulations;
- planning and evaluating municipal MSWM activities by system designers, users, and other stakeholders;
- using waste characterization studies to adjust systems to the types of waste generated;
- physically handling waste and recoverable materials, including separation, collection, composting, incineration, and landfilling;
- marketing recovered materials to brokers or to end-users for industrial, commercial, or small- scale manufacturing purposes;
- establishing training programs for MSWM workers;
- carrying out public information and education programs;
- identifying financial mechanisms and cost recovery systems;
- establishing prices for services, and creating incentives;
- managing public sector administrative and operations units; and
- incorporating private sector businesses, including informal sector collectors, processors, and entrepreneurs.

In the last decade the municipal solid waste management systems in many countries developed more and more as integrated waste management systems based on the concept that all aspects of a waste management system (technical and non-technical) should be analyzed together, since they are in fact interrelated and developments in one area frequently affect practices or activities in another area.

Waste management hierarchy is a key element of integrated solid waste management. The hierarchy ranks waste management operations according to their environmental or energy benefits (*See chapter 4*).

The purpose of the waste management hierarchy is to make waste management practices as environmentally sound as possible. The waste management hierarchy has been adopted in various forms by most industrialized countries. Its principal elements are also included in international conventions and protocols, particularly those dealing with the management of toxic or hazardous waste, and in regional attempts to develop a coordinated policy on the reuse of various byproducts of waste management processes.

Distribution of duties and responsibilities in the MSWM

In most countries, city or municipal governments have an overall responsibility for waste management operations ensuring that collection takes place and that the collected materials are delivered to processors, markets, or disposal facilities. Financing for vehicles, crews, and other equipment is usually provided by the municipal government, which is ultimately responsible for the entire process.

Municipal authorities are responsible for the management of MSW flows in European countries. For this purpose either special municipal agencies or inter-municipal companies are created. They form associations to ensure a higher efficiency of the MSW management.

The introduction of the principle of the producer's extended responsibility for the removal of waste with the expired date of use affected the handling of waste in a number of ways. Those countries where the responsibility for the disposal of certain kinds of waste rests entirely with specialized organizations (Austria, Belgium, Finland, Germany, Luxembourg, and Sweden) the municipality does not bear any expenses for the organization of waste collection. In other countries (Ireland, Italy, and Spain) local authorities collect a fee from the producers of goods for the collection of waste though however it does not completely cover the incurred expenses. Denmark, Greece, the Netherlands and Great Britain do not have a special fund to cover the expenses for the collection of packaging. However, in Denmark all municipalities are obliged to establish and promote the system of paper and glass collection. In the Netherlands local authorities have to comply with the established norms of collection and recycling of packaging. There are no such obligations in the UK and Greece though each municipality has got set targets for waste disposal.

The mentioned waste management hierarchy is advocated in many industrial countries with high standards of living (with waste reduction placed first on the hierarchy), and may not be appropriate for most cities and towns of less developed countries and countries in transition.

Table 9.1 Participation of municipalities and private companies in the collection and recycling of waste in the European Union.

Country	Government body	Participation of private companies	Responsibiilty of the producer
Austria	Municipalities Waste management associations	Collection of MSW –50% Recycling - 80% Composting –50% Constant increase in the involvement in the MSW management	Collection of packaging
Belgium	Municipalities; Intermunicipal waste management associations	Collection and disposal are often carried out by private companies	Packaging Batteries Electronic waste
Denmark	Municipalities; Intermunicipal waste management associations	Collection – 80% MSW landfills and incineration facilities are mainly owned by the state	Not available
Finland	Municipalities and cooperative waste management companies	Private companies are engaged in incineration and other utilization processes	Centralized collection of paper, bottles and cans
Germany	Municipalities	Do not participate in waste collection. Some MSW landfills and incineration facilities are private enterprises. Contracts are carried out through a dual system.	Packaging (label “Green dot”); Batteries
Greece	Municipalities, Associations of municipalities	Limited participation in collection and transportation; are not engaged in recycling	Not available
Ireland	Municipalities	Greater involvement of the private sector in the collection and recycling process; Collection – 40%	Packaging
Italy	Municipalities	Collection – approximately in 46% of municipalities (less in the south, more in the north) Recyling is mainly carried out by state organizations	Fee for packaging (does not fully cover all costs)
Luxembourg	Municipalities Intercommunal associations	Limited participation in composting, incineration and collection	Packaging
The Netherlands	Municipalities Independent state companies	Collection – 33%, are involved in the processing of MSW, more for the biological treatment	Absent
Portugal	Municipalities	Participation in recycling	Data is not available
Spain	Municipalities Autonomous regions State companies	Involved in recycling Are not involved in waste collection	Glass and paper from collection points
Sweden	Municipalities	Collection – 60%	Packaging
The UK	Municipalities (the division of responsibility between processing and collecting organizations)	Collection – 50% of that implemented by the state. Participate in recycling Disposal of waste is carried out by state organizations	Absent

Figure.9.1 Facility for the collection of special waste from the population in the city of Jonköping (Sweden), organized by the waste collection company SITA.

Rather, the first priority for them will be how to divert more organics from the MSW stream (for composting or animal feed). The reason is that organics are, in fact, the largest category of MSW and the greatest reduction in wastes for disposal can be achieved by diverting organics.

The second priority will be, in most cases, supporting maximum reduction/ recovery of synthetic materials, without separate collection by the municipal authority. The solid waste department should encourage waste reduction and materials recovery by the private sector (formal and informal). Municipalities should be cautious about adopting materials recovery programs and technology, although in some cities these may be appropriate.

While waste reduction is not as important in manufacturing as it is for the developed countries, nevertheless, the developing countries and countries in transition need to be alert to the growth of wasteful practices that may result from modern industrial processes and new modes of consumption. With reference to the latter, for instance, there is concern about the problematic increase of thin plastic film as the wastes clog drainage systems. There is a role here for stakeholders to press for legislation and incentives at the national level.

Thus, there are four main ways using which most city governments in developing countries and countries in transition can enhance waste reduction:

- Inform citizens about source separation and recycling, and the needs of waste workers: extensive public education is needed to develop understanding of the need for further source separation to improve the potential for composting and to remove the stigma of association with waste materials.
- Promote recycling industries and enterprises.
- Divert organics. The greatest relief for the waste authority will come from the reduction of organics, which implies, mainly, successful composting. Keeping organics pure for composting will require a more thorough source separation than is done at present.
- Advocate key areas for waste reduction at the manufacturing level (e.g., reduction of plastic packaging; coding of plastics to improve recycling).

9.2 Management of specific waste streams

Specific wastes are those types of solid waste that require special handling, treatment, and/or disposal. The reasons for separate consideration include: 1) their characteristics and quantities (either or both may render them difficult to manage if they are combined with "typical" municipal solid waste); or 2) their presence will or may pose a significant danger to the health and safety of workers and/or the public, to the environment, or both.

Some examples of specific types of wastes are given in Box 9.1 (for information about other specific/hazardous wastes *see Chapter 11*). These wastes are very different from each other, so they should be managed and handled separately if feasible. Typically, in developing countries and countries in transition, specific wastes are set out for collection, collected, and/or disposed along with wastes from commercial businesses and residential generators.

Ideally, these wastes should not enter the municipal solid waste stream, but quite frequently they do, particularly in these countries.

Specific wastes can cause significant health and environmental impacts when managed inadequately. Persons that may come into direct contact with the

Box 9.1 Some examples of specific wastes

Used tires
Used oils
Electrical and electronic waste (e-waste)
Batteries

Figure 9.2 Disassembled parts of electrical and electronic equipment at the waste station in Tallinn, Estonia.

wastes, such as waste collectors and scavengers, may be subject to significant health and safety risks when exposed to some types of special wastes. Toxic components of these wastes can enter the environment, for example, poisoning surface and groundwater bodies.

The management of *used tires* poses a potential problem even for more modern MSWM systems, for reasons related both to the tires' physical properties and their shape. Tires are composed primarily of complex natural and synthetic rubber compounds, both of which have a substantial heating value, and various other materials. The recovery of rubber from used tires can be very energy-intensive, and such processing may generate hazardous substances and other types of process residues.

Illegal stockpiles of used tires can create substantial land use problems, harm the environment, and serve as breeding grounds for insects and other small animals that harbor pathogens that are detrimental to human health. Stockpiles can self-ignite and cause fires that are very difficult to control, resulting in negative human health and environmental impacts.

Used oils are generated primarily in gas stations and in mechanics' shops. These oils generally are discharged in the most convenient location and frequently enter the sewage system, causing problems in the treatment plants or in the receiving bodies of water. When oil is collected haphazardly as part of the MSW stream, it causes problems at the landfill and often becomes part of the landfill leachate.

Some recommended methods of managing used oils are:

- Reuse through retreading for extended service; shredding and grinding for use in road paving material;
- Thermal destruction in cement kilns with subsequent energy recovery;
- Processing in pyrolytic reactors;
- Re-refining into lubricating oil;
- Use as a fuel.

Residents independently deliver car batteries, waste oils, packing from paints, fluorescent and other lamps, bulky waste, etc. to the facility.

The practical solution to the management of *e-waste* is the implementation of segregated collection and adequate processing. Current methods for the treatment of e-products include mechanical and chemical processing of the products for the recovery of valuable materials and the removal and/or reduction of the toxicity of the residue.

There are reasons to separate the electronics waste stream:

- rapid growth of the electronic manufacturing volume, market, and rapid change in technology resulting in new products
- complexity of electronic products, which requires special approach to recycling
- use of rare and precious metals and compounds, many of which should be recovered
- presence of toxic chemicals and other substances of environmental concern
- opportunities of efficient material and component reuse

Electronics recycling, for instance, that of computers is essentially a process of breaking down the final product back to components (some of which can be reused) and initial raw materials (such as copper, gold, silver, other metals, and plastics). Because of a significant load of the technological product with heavy metals and toxic compounds (e.g., mercury, cadmium, lead, flame retardants), discarded electronics is classified as *hazardous waste*. Hence, recycling also requires strict measures of environmental safety.

However, currently existing programs of sorting/disassembly are hardly sufficient. The problem is that current computer and other electronic products are not designed to be recycled. End-of-life disassembly and recovery of pure materials is a tedious and expensive process. Few companies manage to build an effective infrastructure for electronic recycling. Even if responsible recycling practices exist, they hardly keep up with the growing market for electronics and accelerating e-waste accumulation pace.

Figure 9.3 The EU countries as well as some CIS countries already collect household batteries in shopping centers. Any customer coming to do shopping can place used batteries into a specifically located and labeled container in the supermarket. Their further collection and disposal are carried out by a specialized organization that handles wastes (as a rule, this is an organization that is involved in all stages of handling municipal waste).

Used batteries are typically generated by car maintenance facilities and vehicle battery suppliers. This type of battery contains acid and lead, both of which are hazardous to humans and to the environment if not properly managed. Environmentally acceptable processing of wet batteries for materials recovery requires trained and experienced facility personnel. Recycling of batteries typically involves draining and neutralization of the acidic liquid, and the recovery of the lead in a non-ferrous foundry.

9.3 Management of food waste

The term "food waste" refers to the putrescible waste generated in the preparation and consumption of food and that remaining after consumption (i.e., "kitchen" and restaurant wastes); discarded comestibles (e.g., spoiled or partially eaten fruit, stale bakery goods, etc.); and vegetable trimmings generated in produce markets, so called "yard waste".

From a life cycle perspective, the term "food waste" can be used to include large sources of biogenous waste (biowaste) along the food production chain. A tentative list is shown below:

- losses after harvesting
- losses during transportation to industry
- losses and surplus from food industry
- residues from markets
- residues from restaurants and catering
- leftover food of different origin
- household food waste

Figure 9.4 Examples of food waste.

Food waste is approximately 14% of the household waste we discard. Food waste is of concern as methane gas emissions, a very potent greenhouse gas, and the methanogens that food waste supports in landfills also cause the mobilization of other pollutants in landfills, resulting in an increase in both air pollutants and leachate.

Food waste decomposes readily and under proper conditions enhances the compostability of yard wastes, especially of shrub and tree trimmings and leaves by serving as a readily available microbial energy source and to a limited extent as a nitrogen source for the microbial populations.

Ideally, food waste should be composted. If you have a compost bin where you live, you can incorporate food waste into your home compost – if not, consider setting up a home compost system. Home composting avoids transportation of organic wastes, saving fuel and other resources associated with transporting waste.

The composting of yard waste and food waste is encumbered usually by the difficulty in reconciling the seasonal variations in yard waste production with the year-round uniformity of food waste production. The problem is less significant in tropical climates. Because of the difference in patterns of generation, yard waste can be in short supply during slack growing seasons (e.g., rainy season, late autumn and winter). However, the dearth of yard waste is a problem only if the composition of the food waste is such that a bulking agent would be needed, since yard waste can be an excellent bulking agent.

Composting of yard waste processed for that purpose may be carried out at the site of the processing facility (*more about composting see in Chapter 8*).

9.4 Exchange of waste

Waste exchange can be defined as an operation that engages or assists in the transfer of either waste materials or information concerning waste materials. Practically always companies producing their principal products, will also generate a waste stream. In cases where these materials have market value, they are known as a by-product, and are sold or reused if their value justifies the cost of transportation, testing, handling, and recycling. If materials have no recognized value, they are typically referred to as waste and are discarded.

Waste exchange can assist in the reuse of these wastes if the generator determines that the economic factors, such as the cost of virgin raw materials, the exchange value of the waste, the waste management cost, the transportation cost, and the purity of the waste stream, are not conductive to their reuse. A waste exchange system can help find the user (and some cases a buyer) for these wastes.

Waste exchange can potentially maximize off-site recycling opportunities.

A great deal has been done for the establishment and operation of waste exchanges. In the past many failed, partly due to financial reasons but also due to geographic reasons - where their area of operation was constrained, or finding matching industries (generators and recyclers) for the exchange of waste was difficult. National listings to which local and regional exchanges have access to can provide a solution to this.

There are also sometimes regulatory constraints on hazardous waste exchange, where the liability for the hazard remains with the generator even when the exchange has taken place.

In the USA, for example, the value of publicly funded waste exchanges has been favorably compared to the costs of other publicly funded re-use and recycling efforts.

9.5 LCA approach to waste management systems

Life Cycle Assessment (LCA) is an analytical framework that is normally focused on resource consumption and on impacts to human health and the environment associated with the manufacturing of a specific product. The main advantage of LCA is that it alleviates problem-shifting considering the full range of relevant impacts.

Technologies for waste management are ever-improving, and the number of different ways for treating waste is increasing. It is, therefore, necessary to find ways to assess the most optimal forms of waste treatment. One of the assessment methods that has arisen to help perform this task is the life cycle assessment.

The point of origin in a waste management system is always at the site of the waste generation. Here the waste can either be sorted into a predefined quality by the waste producer or shipped directly for treatment. From the waste producer, collection schemes are set up to handle the collection of waste and transport it to the treatment facilities. The collected waste will either go first to an intermediary treatment facility (for example, a material recovery facility, compost facility, anaerobic digester or transfer station) from where it will go to a final treatment facility (landfill, biological matter used in agriculture, material recycling).

LCA is an internationally standardized methodology for environmental assessment, which is used to evaluate the environmental impact of a product or system. The life cycle assessment for waste management systems is designed according to the same principles as LCA for products and processes, the major steps in the LCA of waste management systems are:

- scope definition (defining system boundaries and parameters);
- inventory analysis (identifying inputs and outputs of all processes in lifecycle);
- impact assessment (setting assessment criteria; quantifying the environmental impact);
- data interpretation (analyzing and comparing all impacts and performing sensitivity analysis).

With the above listed four consecutive stages, LCA is still an iterative process; i.e., the results of data interpretation can help fine-tune the earlier phases of the analysis.

LCA for traditional products are normally referred to as the "cradle-to-grave" scope, which means that all emissions are accounted for from the extraction of the materials for a product, the production of the product, the use of the product, and finally the disposal of the product. In a waste LCA it is not often possible to get information about the life cycle of the product before it ends up in the waste bin, or it is not possible for the waste handler to control this part of the chain. Therefore, waste management LCA is most often a bin-to-grave LCA. This means that only the collection, transportation to the treatment facility and the treatment/disposal process itself are accounted for.

The inventory analysis is where all emissions into the environment, energy production and use and resource consumption are tallied. This is one of the main functionalities of the LCA waste models, as this is where they gather all the data required for the third step of the LCA (the impact assessment).

One of the key stages of LCA is impact assessment, because it generates numerical data that can directly affect conclusions from this assessment. The main four steps in impact assessment are:

- setting assessment criteria;
- defining or choosing scoring system (model);
- normalization of impacts;
- weighing of impacts.

During each step in the waste management system, a number of direct or indirect impacts take place. Emissions from the waste treatment process itself (e.g. methane released from a landfill) or from the use of auxiliary materials and energy are released into the environment. Furthermore, if the energy is produced as the product of a treatment process, it might impact the surrounding system by replacing energy that would have been needed to be produced elsewhere. This is what is called "indirect effects". Finally, materials in the waste stream might be recycled and turned into new materials, thereby replacing the need for virgin production of the same material.

The implementation of LCA models in solid waste management requires large amounts of data – both direct and indirect. Access to these datasets, anyway, might be limited, as data providers often only cover the ata they are legally required to report. This makes it hard to assess if all the important emissions are included, or if some critical emissions or other data are missing from the inventory. One way this could be remedied would be to look at similar processes in LCA databases and see whether they include other important emissions that should be monitored. This is, of course, only possible for direct data that can be measured. The issue is the same for marginal data, which is required in a consequential LCA study. In this instance, it might sometimes be necessary to compromise, as it is possible to neither get data for a marginal process nor establish what the marginal process is. In that case, it will be necessary to use average (attributional) data.

The process of implementing LCA models in solid waste management is already taking place, and as the amount of models and availability of data increase, the interest in such models grows too.

Some LCA management waste models are available on the Internet and they can easily be used on-line, for instance, a Swedish model WAMPS developed in IVL - Swedish Environmental Research Institute: *https://wamps.ivl.se/*

Chapter 10
Landfills as a Widespread Type of Waste Treatment

10.1 Municipal solid waste landfills: purpose and construction

MSW landfills are the simplest and therefore, the most widespread facility for land disposal (or storing) of waste in the world.

Landfilling means placing waste on a specially designed, exploited and controlled waste disposal territory. A MSW landfill (formerly called 'dump') is a complex environmental facility designed for storing, isolation and neutralization of solid municipal waste, which protects air, soil, surface and ground waters from pollution, prevents the proliferation of rodents, insects and pathogenic microorganisms. The principal goal while designing and exploiting landfills is to isolate waste, its decomposition and transformation products from the environment both during the landfill functioning and after its closure.

Modern landfills must comply with the requirements concerning the choice of site, structure, exploitation, monitoring, closure and financial guarantees (accident insurance and so on).

Each landfill has its own design features depending on its specificity and local conditions. Nowadays there are no standard landfill designs, since each landfill is unique and only separate structural joints and processes can be typified.

Thus, the sites used for storing MSW are very different, too. A MSW landfill can be located in a ravine, on a flat surface or in an exhausted mine.

While choosing a site it is necessary to avoid the vicinity of airports, water reservoirs, ground water exposure pathways, marsh lands, tectonic fractures and seismically dangerous zones.

A landfill design must provide measures to protect the environment from being polluted with waste decomposition products, with most economical use of space set aside for storage. The following methods can be applied for this purpose:

- Waste isolation securing total sanitary-hygienic safety of the population living outside the sanitary protection zone, as well as the safety of the landfill staff.
- Securing the static stability of the stored waste with the allowance of gas emission dynamics, hydrological conditions and waste compaction.
- Enabling further use of the territory after the landfill closure.

Figure 10.1 A design model of a new landfill to be built in the town of Soligorsk, Minsk region, Belarus. Many waste landfills currently operating in Belarus are not equipped with leachate and landfill gas collection systems, as well as other facilities.

Modern MSW landfills are designed with landfill gas collection systems and the facilities for protecting soil and surface waters.

The bottom of the pit is covered with a geomembrane and then filled with a meter-width layer of clay. The geomembrane is a modern waterproofing material that can also function as a drainage blanket. This protective layer is created to prevent leaching from contaminating soil and ground water. Waste is put in layers and then at the end of each day rammed with a compactor and covered with a layer of clay (15-30cm). This is done to prevent the proliferation of odour and dispersion of waste by wind. When filled with waste, the pit is roofed and covered with a protective coating. The roof is made of compacted clay put over waste and is thicker than the usual everyday layer and the layer over the geomembrane. The protective coating is made of soil and vegetation.

The pit is equipped with engineering structures designed to remove liquid and gaseous SMW decomposition products. Apertures, pipes and pumping equipment are installed in the pit. Landfill gas produced by waste decomposition is collected and sent to be purified and, if necessary, enriched.

Safe exploitation of landfills is ensured by the following measures:

- Exclusion of hazardous waste and keeping accurate record of all received waste and their location on the landfill;
- Ensuring everyday covering of waste with soil or special foam to prevent it from being washed or blown away.
- Fighting disease carriers (rats and others), usually by means of special poisons.
- Pumping out explosive gases from the landfill interior.
- Preventing the uncontrolled access to the landfill by people and animals; the landfill must have perimeter fencing and be guarded.
- Hydraulic structures must minimize precipitation and surface water inflow to the landfill.
- Surface water runoff from the landfill must be treated; the liquid exuded from waste must not get into ground water, which is secured by special water-diversion and waterproofing systems.
- Chemical monitoring of air, ground and surface waters in the vicinity of the landfill must be performed regularly.
- The analysis of MSW storage practice shows that landfilled objects have a long-lasting negative impact on the environment.

The main types of possible environmental impact of landfills are polluting air with waste decomposition products (biogas); polluting ground and surface waters with landfill leachate; soil contamination and bacteriological pollution of the surrounding area.

Biogas (landfill gas) extraction from the landfill helps to reduce the emission of methane and organic compounds; prevent gas outbursts, explosions and fires; control its migration. The choice of extraction (degassing) technology depends on such factors as the landfill construction and age; the type of waste (the content of organic substances); the volume and depth of the landfill; the local conditions (geological conditions, position, utilization of the surrounding territory). But the most important factor is the amount of generated biogas.

Landfill leachate is generated because of the natural humidity of waste (40-70%), infiltration of atmospheric precipitation, biochemical processes accompanied by water production. Leachate is characterized by a high content of organic and inorganic substances (exceeding the MPC by hundreds of times). They act as a source of pollution for surface and ground waters in the vicinity of the landfill practically at all stages of its life cycle. They can also contain pathogenic microorganisms and therefore constitute sanitary-and-epidemiologic danger. Landfills usually employ systems of drain-pipes and pipelines to collect and drain leachate. Collected leachate can be sent to the landfill treatment facilities (for mechanical, biological and physicochemical treatment) or to municipal treatment facilities.

To secure safe disposal of waste it is necessary to perform special measures and use protective means known as barriers. Multibarrier protection implies using a complex of organizational and technical measures aimed at reducing emissions of contaminating substances from the landfill.

The technological process of waste disposal is usually performed by pit method, thus allowing to implement reclamation measures incrementally, without having to wait for the landfill closure.

There are three main stages in the landfill operation:

1. The active stage of landfill operation lasting 15-20 years. In this period the landfill is filled with waste.
2. The stage after the landfill closure when biochemical processes in the body of the landfill slow down (this stage can be called a bioreactor for convenience). In this period the processes of biochemical decomposition of waste are naturally-driven, i.e. they are not boosted by any technological means.
3. Post-closure period, when the landfill is adapted to the environment.

The overall duration of the bioreactor and the adaptation periods can last hundreds of years. To make the adaptation period shorter and reduce the operation cost and environmental impact, modern landfill technologies are designed so as not only to reduce potential contaminating emissions, but also to manage (to accelerate or slow down) the natural processes of waste biodegradation.

The *advantages* of MSW landfilling as a treatment method are its relatively low energy intensity, labour inputs and waste disposal cost as compared with the other methods.

The *disadvantages* of landfilling are the following: occupying large territories that become unusable for tens of years; the risk of environmental pollution if the operating instructions are not followed; long-lasting active processes occurring in the body of the landfills, which produce potentially polluting substances.

The analysis if MSW treatment over the last 20 years shows that there is a consistent tendency towards the reduction of the amount of landfilled waste. Thus, the European Union Directive 1999/31/EC on the landfill of waste aimed at reducing the quantity of landfilled waste by implementing restrictions on the composition of biodegradable waste and a ban on landfilling unsorted waste.

Landfilling is the least preferred method of waste management according to the hierarchy of waste treatment methods. The role of energy recovery and waste recycling has been steadily increasing in the world. Despite this tendency, landfills still remain and will remain for a longer time a necessary element in any system of waste management. In Eastern Europe and Central Asia landfills will remain the main treatment method for at least 20 more years due to the existing economic and environmental protection's conditions.

10.2 Landfill gas: Generation, collection and utilization

The generation of landfill gas is the result of waste decomposition under anaerobic conditions (without oxygen). Waste is decomposed by methanogenic and acidogenic bacteria. Acidogenic bacteria break down waste into volatile fatty acids having the maximum methane production capacity. Methanogenic bacteria transform volatile fatty acids into methane CH_4 and carbon dioxide CO_2. Consequently, landfill gas is composed of approximately 50% methane CH_4 and 50 % carbon dioxide CO_2, with a small proportion of H_2S and other organic substances.

The average readings show that total decomposition of 1 ton of SMW produces no less than 100-200 m^3 of landfill gas.

This gas is equal in its properties to the natural gas, and its collection is a profitable business. Of course, prior to collection it is necessary to equip the SMW landfill with all the required devices and pipelines. Biogas utilization at the landfill requires provision of special facilities (isolating barrier, gas collector, gas wells, etc.), but these investments have a short payback period.

Since the process of waste decomposition is rather slow and may take tens of years, the landfill can be regarded as a stable source of biogas. The scope and stability of production, location near urbanized territories and low collection cost make landfill gas a perspective source of energy that can be used to meet the local needs. Simultaneously it helps to solve the environmental problems of polluting ground waters and air.

Landfill is a humid gas mixture mainly composed of methane CH_4 and carbon dioxide CO_2, and therefore it cannot be used as a fuel in its humid form.

Thus, landfill gases must be collected, purified and then utilized. For this purpose, special gas outlets must be built during the landfill construction. They will transfer gas to the storage places, where it will be purified.

To purify landfill gas from impurities and make it usable, special scrubbers are used. They purify gas by washing it with any liquid. This method permits to totally remove aerosol particles, hazardous substances and dust from gas.

Figure 10.2 Water steam and gas emissions due to the biochemical decomposition of waste at the landfill.

Figure 10.3 Extraction and transportation of landfill gas from the landfill body.

Landfill gas contains methane and therefore can be used in general purpose gas mains. But due to the high content of carbon dioxide CO_2, it should be enriched prior to utilization.

Landfill gas enrichment is the process aimed at increasing methane content to 94-95% (like in the natural gas). This process is carried out in special facilities. Enriched gas can be used in municipal general purpose mains to produce heat and steam or as an automobile fuel. It can also be used as a fuel in gas-turbine or gas-piston units to generate electric power.

Landfill gas collection is most profitable from the landfills greater in depth than 10 meters and containing more than 1 million tons of waste. It is desirable that the bulk of waste should not be older than 10 years. If these conditions are met, the quantity of landfill gas collected per 1 ton of solid municipal waste is usually no less than 5 m^3 per year. This is especially profitable since the collection volume will remain the same over the next 20 years.

It can be seen from table 10.1 that the global volume of landfill gas collection exceeds 1.2 billion m^3 per year, which is equivalent to 429 thousand tons of methane (1% of global methane emission). The volume of collected gas is insignificant as compared with its generation. But we can suggest that its role will increase in the future due to enormous waste deposits and development of technologies.

Negative impact of landfill gas. While having numerous utilization opportunities and evident advantages, landfill gas still has a range of drawbacks. It contains toxic and hazardous substances that can affect people's lives and health and produces destructive influence on the vegetation surrounding the landfill and on its surface. If proper control is not exercised over landfill gas generation and collection, the landfill body can be destroyed by an inner pressure release. Besides, landfill gas is a *greenhouse* gas.

The issues of landfill gas generation and minimization of its environmental impact remain topical. But organized properly, landfill gas collection and utilization is a reasonable, promising and justified solution from the ecological and economic points of view.

10.3 Reclamation of MSW landfills

As has already been stated, special attention should be paid to the decommissioning and reclamation of landfills when they are filled or their operation term has expired. As a rule, the initial plan of a landfill must include a plan of reclamation and long-term monitoring activities after the landfill closure.

Table 10.1 The global landfill gas collection volume (without the newly implemented collection in 2010 -2014)

Country	The volume of landfill gas collection, mln m^3 p.a.
USA	500
Germany	400
Great Britain	200
Netherlands	50
France	40
Italy	35
Denmark	5
Total	1230

Figure 10.4 A landfill in Rönneholm, the south of Sweden. The landfill is still operating, but some pits have already been closed and reclaimed. On the left there is a reservoir for leachate collection and treatment.

Landfill reclamation is a complex of activities aimed at organizing the system of surface isolation, creating a fertile root layer and restoring living (biotic) components (microorganisms, fungi, higher plants) – the so-called biological reclamation. Post-reclamation use of MSW landfills embraces several areas: forestry, recreational sphere (ski hills, stadiums, sports grounds), civil engineering, construction of commercial or industrial facilities (warehouses, parking bays, lightweight constructions). The character of this future utilization and reclamation costs must be factored in at the landfill design stage.

Thus, the reclamation of MSW landfills is a complex of activities aimed at restoring the economic value and productivity of the reclaimed territories. Besides, these activities are aimed at improving the environmental conditions.

The reclamation process starts immediately after the ceasing of waste landfilling. This procedure comprises two separate stages: the technical and the biological ones.

The technical stage embraces designing technological and constructional measures, solutions for installing protective screens over the landfill surface and foundation, creating facilities for biogas collection, purification and utilization and for leachate and surface waste water collection and treatment.

The biological stage of reclamation comprises a complex of agrotechnical and phytomeliorative measures aimed at restoring disturbed lands. This stage follows the technical stage of reclamation. The measures implemented at the biological stage include tillage, the choice of plants, sowing.

In each separate case the choice of design solutions concerning the reclamation of the closed landfill is made on the basis of the previously made engineering investigations.

Chapter 11
Hazardous Waste, from Households and Industry

11.1 Collection, treatment and safety management of hazardous waste

A solid waste is classified as a hazardous waste and is subject to regulation if it meets any of the following four conditions: ignitability, corrosivity, reactivity, or toxicity.

Hazardous wastes can from in households and are generated in large volumes at each industrial enterprise and when providing services.

Quantities of *hazardous wastes* such as oil-based paints, paint thinners, wood preservatives, pesticides, insecticides, household cleaners, used motor oil, anti-freeze, mercury containing fluorescent lamp, and batteries generated by house-holds have been estimated to make up a total of about 0.5% (by weight) of all waste generated at home or less.

There are no specific, cost-effective sound practices that can be recommend-ed for the management of household hazardous wastes in particular countries. Rather, since concentrated hazardous wastes tend to create more of a hazard, it is best to dispose of household hazardous wastes jointly with the MSW stream in a landfill, where the biological processes tend to exert a fixating effect on small amounts of toxic metals, while other toxic substances are diluted by the presence of MSW or are broken down into less toxic intermediates during the process of decomposition in the fill.

Figure 11.1 Hazardous waste from households at the waste collection station SYSAV in Malmo, Sweden

Table 11.1 Health effects of selected hazardous substances

Chemical	Source	Health effect
Pesticides DDT Benzene hexachloride (BHC)	Insecticides Insecticides	Cancer; damage to liver, embryos, bird eggs Cancer, embryo damage
Petrochemicals Benzene Vinyl chloride	Solvents, pharmaceuticals and detergents Plastics	Headaches, nausea, loss of muscle coordination, leukemia, damage to bone marrow Lung and liver cancer, depression of central nervous system, suspected embryo toxin
Other organic chemicals Dioxin Polychlorinated Biphenyls (PCBs)	Herbicides, waste incineration Electronics, hydraulic fluid, fluorescent lights	Cancer, birth defects, skin disease Skin damage, possible gastro-intestinal damage, possibly cancer-causing
Heavy metals Lead Cadmium	Paint, gasoline Zinc, batteries, fertilizers	Neurotoxic; causes headaches, irritability, mental impairment in children; brain, liver, and kidney damage Cancer in animals, damage to liver and kidneys

The regulations govern the collection and management of these widely generated wastes, thus facilitating environmentally sound collection and proper recycling or treatment.

These regulations also ease the regulatory burden on retail stores and others that wish to collect these wastes and encourage the development of municipal and commercial programs to reduce the quantity of these wastes going to municipal solid waste landfills or combustors. In addition, the regulations also ensure that the wastes subject to this system will go to appropriate treatment or recycling facilities pursuant to the full hazardous waste regulatory controls.

The amount of mercury in a fluorescent lamp ranges between 3.5 to 15 milligrams, depending on the type of the fluorescent lamp, the manufacturer, and the date of the manufacturing. Although lighting manufacturers have greatly reduced the amount of mercury used in lighting over the past 20 years, they are not yet able to completely eliminate the need for mercury. Although the amount of mercury in a single fluorescent lamp is small, collectively, large numbers of fluorescent lamps contribute to the amount of mercury that is released into the environment.

Human health hazards occur because of the chemical and physical nature of the waste, and its concentration and quantity; the impact also depends on the duration of exposure. Adverse effects on humans range from minor temporary physical irritation, dizziness, headaches, and nausea to long-term disorders, cancer or death. For example, the organic solvent carbon tetrachloride (CCl_4) is a central nerve system depressant as well as an irritant and can cause irreversible liver or kidney damage.

Transportation spills and other industrial processes or storage accidents account for some hazardous waste releases. Such releases can result in fires, explosions, toxic vapors, and contamination of groundwater used for drinking.

Danger arises from improper handling, storage, and disposal practices. At hazardous waste sites, fires and explosions may result from investigative or remedial activities such as mixing incompatible contents of drums or from introduction of an ignition source, such as a spark from equipment.

A producer/generator of hazardous waste may accumulate hazardous waste on-site, provided the following requirements:

- *Proper Storage.* The waste must be properly stored in containers or tanks marked “Hazardous Waste” with the date accumulation began.
- *Emergency Plan.* A contingency plan and emergency procedures are developed. Generators must have a written emergency plan.
- *Personnel Training.* Facility personnel must be trained in the proper handling of hazardous waste.
- Proper packaging to prevent hazardous waste leakage under normal or potentially dangerous transport conditions such as when a drum of waste falls from a truck or loading dock;
- Labeling, marking, or placarding of the package to identify characteristics and dangers associated with the waste.

Transporters of hazardous waste are the critical link between the generator and the ultimate off-site treatment, storage, or disposal of hazardous waste.

A transporter is subject to national regulations including obtaining a registration number, complying with the national hazardous waste management system, and dealing with hazardous waste discharges.

Treatment, storage, and disposal facilities (TSDs) are the last link in the cradle-to-grave hazardous waste management system. All facilities handling hazardous waste must obtain operating permits and abide by treatment, storage, and disposal regulations.

Owners and operators must:

- *Conduct waste analyses* before starting treatment, storage, or disposal in accord with a written waste analysis plan. The plan must specify tests and test frequencies providing sufficient information on the waste to allow management to act in accordance with the laws, regulations, and codes.

- *Install security measures* to prevent inadvertent entry of people or animals into active portions of the TSD. The facility must be surrounded by a barrier with control entry systems or 24-hr surveillance. Signs carrying the warning “Danger! Unauthorized Personnel Keep Out!” must be posted at all entrances. Precautions must be taken to avoid fires, explosions, toxic gases, or any other events threatening human health, safety, and the environment.
- *Conduct inspections* according to a written schedule to assess facility compliance status and detect potential problem areas. Observations made during inspections must be recorded in the facility’s operating log and kept on file for 3 years. All problems noted must be remedied.
- *Conduct training* to reduce the potential for mistakes that might threaten human health and the environment. In addition, each TSD has to implement a hazard communication plan, a medical surveillance program, and a health and safety plan. Decontamination procedures must be in place and employees must receive a minimum of 24 hr of health and safety training.
- *Properly manage ignitable, reactive, or incompatible wastes.* Ignitable or reactive wastes must be protected from sources of ignition or reaction, or be treated to eliminate the possibility. Owners and operators must ensure that treatment, storage, or disposal of ignitable, reactive, or incompatible waste does not result in damage to the containment structure, or threaten human health or the environment. Separation of incompatible wastes must be maintained.
- *Comply with local standards* to avoid setting new facilities in locations where floods or seismic events could affect waste management units. Bulk liquid wastes are prohibited from placement in salt domes, salt beds, or underground mines or caves.

Not all wastes can be eliminated through source reduction or recycling. Most manufacturing waste products require treatment to destroy the wastes or render them harmless to the environment. Technological options for waste handling depend upon waste type, amount, and operating cost.

Numerous chemical, physical, and biological treatments are applicable to hazardous wastes. Many such treatment processes are used in by-product recovery and volume reduction processes. All wastes should first be surveyed and classified to determine which treatment or destruction process should be used.

Hazardous wastes may be organic or inorganic. Water will dissolve many of these substances, while others have limited solubility. Sodium, potassium, and ammonium salts are water soluble, as are mineral acids. Most halogenated inorganics, except fluoride, are soluble while many carbonates, hydroxides, and phosphates are only slightly soluble. Alcohols are highly soluble, but aromatics and long-chained petroleum-based organics are of low solubility. Solubility is critical in chemical treatment processes.

Incineration offers advantages over other hazardous waste treatment technologies, and certainly over landfill operations. Incineration is an excellent disposal technology for all substances with high heat release potentials. Liquid and solid hydrocarbons are well adapted to incineration. Incineration of bulk materials greatly reduces the volume of wastes. Any significant reduction in waste volume makes management simpler and less subject to uncertainty.

The four major subsystems of hazardous waste incineration are:

- waste preparation and feeding,
- combustion chamber(s),
- air pollution control, and
- residue and ash handling.

Chemical and physical waste treatment processes are used for removal rather than destruction. A more appropriate term for non-destructive processes is concentration technologies. Physical treatment processes use physical characteristics to separate or concentrate constituents in a waste stream. Residues then require further treatment and ultimate disposal. Chemical treatment processes alter the chemical structure of wastes, producing residuals that are less hazardous than the original waste.

11.2 Medical waste

Medical waste is the waste generated in the process of providing health care and activities of health care establishments.

Waste generated within hospital premises has three main components: common wastes, for example, administrative office waste and kitchen waste; pathogenic or infectious wastes (these also contain sharps); and hazardous wastes (mainly those originating in the laboratories containing toxic substances). The quantity of the first type of waste tends to be much larger than the second and third types.

Pharmaceutical waste, for instance, expired medicines, make up a separate group of medical waste.

Medical waste is one of the most problematic types of wastes for a municipality or a solid waste authority. When such wastes enter the MSW stream, pathogens

Figure 11.2 Examples of medical waste

in the wastes pose a great hazard to the environment and to those who come in contact with the wastes.

The structure of medical waste can be quite diverse since the definition of medical waste includes everything thrown away by health care establishments. Medical waste includes:

- Plastic (used syringes, droppers and other disposable equipment)
- Metal (piercing and cutting tools),
- Paper (packaging),
- Catering waste,
- Glass (ampoules, vials),
- Biological material,
- Chemicals (expired medicines, mercury-containing devices), etc.

Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal identifies 45 types of hazardous waste. The list opens specifically with clinical waste. This shows the extent to which this waste is dangerous to humans. Thus, it is clear why most countries of the world classify medical waste as an especially hazardous waste. The problem is that the amount of medical waste demonstrates an intensive and stable tendency to grow.

At home, people usually dispose of unnecessary drugs and expired medications by flushing them down the drain. This method of disposing causes sewage pollution. Sewage treatment plants do not remove such a specific kind of pollution and untreated water has a negative impact on the underwater flora and fauna. Upon the reuse of such water people may also be exposed to the impact of chemical compounds that medications consist of.

If such waste is simply thrown to MSW landfills then there is a risk of the spread of bacteria leading to the groundwater contamination and the spread of infections. This, in turn, may lead to real epidemics.

Therefore, one should strive for comprehensive medical waste management such as the minimization of waste forming and sorting at the place of origin.

Segregation of medical waste types is recommended as a basic waste management practice. However, thorough separation is possible only when there is significant management commitment, in-depth and continuous training of personnel and permanent supervision to ensure that the prescribed practices are being followed. Otherwise, there is always a risk that infectious and hazardous materials will enter the general MSW stream.

Sound practices for managing medical wastes are characterized by:

- *source separation within the hospital,* (a) that isolates infectious and hazardous wastes from non-infectious and non-hazardous ones, through color coding of bags or containers; (b) that source separates and recycles the large quantities of non-infectious cardboard, paper, plastic, and metal; (c) that source separates compostable food and grounds wastes and directs them to a composting facility if available; and (d) that is characterized by thorough management monitoring;
- *take-back systems,* where vendors or manufacturers take back unused or out-of-date medications for controlled disposal;
- *tight inventory control over medications,* to avoid wastage due to expiration dates (really a form of waste reduction);
- *piggy-back systems for nursing homes,* clinics, and doctors' offices, so that they can funnel their wastes through hospital waste systems in the vicinity;
- *treatment of infectious waste through incineration, or by disinfection* (including autoclaving, chemical reaction, microwaves, and irradiation). In the case of incineration this may be done within the hospital premises or in a centralized facility. An incinerator is difficult and expensive to maintain, so it should be located in a hospital only when the hospital is large or where it provides services to other nearby hospitals. Otherwise, a centralized incinerator that provides services to hospitals in one region or city is more appropriate. In the case of disinfection, residues from these processes should still be treated as special wastes, unless a detailed bacteriological analysis is carried out.
- *proper disposal of hospital wastes.* In many developing countries none of the above treatment systems are widely available, so the final disposal of infectious and hazardous components of the wastes is necessary. Since in many developing countries there are no landfills specifically designed to receive

special wastes, hospital wastes need to go to the local landfill or dump. In this case, close supervision of the disposal process is critical in order to avoid contact with waste pickers. Final disposal should preferably be done in a specially designated cell, which should be covered with a layer of lime and at least 50 cm of soil. When no other alternative is available for final disposal, hospital wastes may be disposed of jointly with regular wastes. In this case, however, hospital wastes should be covered immediately by a meter thickness of ordinary MSW and always be placed more than two meters from the edge of the deposited waste.

The European Union Directive on the disposal of waste prohibits the disposal of medical waste generated during medical and veterinary practices if these wastes can be infectious.

The European Union Directive on incineration of waste sets specific standards on the emission of pollutants from the combustion of medical waste.

Strict regulations on pollutant emissions from the combustion of medical waste led to the closure of many incineration plants and the development of a great number of ways for the disposal of infectious medical waste. Technologies which are not based on incineration prevent the formation of dioxins, so their use does not violate the regulations of the Stockholm Convention on Persistent Organic Pollutants (POPs) which entered into force in May 2004. However, the rates of spread of new alternative methods of medical waste disposal are low so incineration remains the main method in Europe.

Many EU countries have created return systems for medicines that allow to return unwanted or unused medications to pharmacies. In some countries the return system is managed by the pharmaceutical industry while in others municipalities do it.

The return system for unused medications and expired medicines is a part of the ecological policy of the European Federation of the Pharmaceutical Industry. At present the return system as a special service offered by pharmacies is available to 90% of the European citizens.

11.3 Management of hazardous and medical waste in the Republic of Uzbekistan

The management of hazardous waste and medical waste is regulated by law in the Republic of Uzbekistan.

The Law of the Republic of Uzbekistan “On Waste” (2002) defines hazardous waste as the waste containing substances that have at least one of the hazardous properties (toxicity, infectious nature, explosivity, flammability, high reactivity, radioactivity) and are present in such an amount and come in a form that present an immediate or potential danger to life and health of the people, the environment both independently and when in contact with other substances.

Sanitary rules and norms of the collection, storage, and disposal of waste in medical institutions in the Republic of Uzbekistan (2015) define the rules for the collection, storage, processing, and removal of all types of health care facilities waste.

The legislation of the Republic of Uzbekistan defines hazardous waste in the following way:

Hazardous waste is solid and liquid waste or a mixture thereof that due to their nature and concentration of chemical or infectious components and physical factors in them:

- Can be the cause (or to a great extent contribute to) of the increase in the mortality rate or the increase in the frequency of serious and irreversible illnesses as well as illnesses that lead to disability;
- In the event of improper handling, storage, transportation, disposal, processing can create at present or in the future a potential danger to human health or the condition of the environment;
- Are hazardous due to social, aesthetic, and ethical reasons if the waste is formed due to infected waste, toxic and radioactive components and unchanged anatomical waste.

Depending on the degree of their epidemiological, toxicological and radioactive hazards as well as the negative impact on the environment medical wastes are divided into **five** classes of danger:

- **Class A – non-hazardous** – have no contact with the bodily fluids of the patients, infectious patients; non-toxic wastes include food wastes from all departments of the medical facility except infectious ones; furniture, fixtures and faulty diagnostic equipment that do not contain any toxic elements; uninfected paper, etc.
- **Class Б – hazardous (risky)** – potentially infected wastes: materials and tools contaminated by bodily fluids (including blood, secretions of patients), pathological and anatomical waste; organic surgery waste (organs, tissues, etc.); waste from infection departments (including food); wastes from microbiological laboratories working with microorganisms of the 3-4 groups of pathogenicity; biological waste from vivariums.
- **Class B – extremely hazardous** – all materials that come in contact with patients with highly dangerous infections; wastes from microbiological labo-

ratories working with microorganisms of the 1-2 groups of pathogenicity; TB waste; waste from patients with an anaerobic infection.

- **Class Г – wastes similar to industrial waste in their composition** – expired medicines; wastes from medicinal and diagnostic products; expired disinfectants that are not to be used; cytostatics and other chemical products; things, devices and equipment containing mercury.
- **Class Д – radioactive waste** – all types of waste containing radioactive elements in any aggregate condition in which the radionuclide content exceeds all permissible levels set by the standards of radioactive safety.

The system of collection, transportation, temporary storage, handling and disposal of medical waste in the Republic of Uzbekistan includes the following stages:

- collection of waste within the organizations engaged in medical and/or pharmaceutical activities:
- moving wastes from the units and storing them temporarily on the territory of the organization generating waste;
- disinfection;
- transportation of waste from the territory of the organization generating waste;
- decontamination of waste generated;
- final disposal of disinfected medical waste.

Mixing of waste of different classes in one container is unacceptable. Uzbek legislation provides that when planning the facilities for the storage of hazardous chemical waste it is required to take into consideration the features of the chemical elements subject to storage and disposal (flammability, corrosivity, explosivity).

The place for storage should be indoors and separate from other waste repositories. When storing liquid chemicals the storage facility should be equipped with a water and chemical resistant drain. In the absence of a runoff storage special containers for the collection of flowing liquids should be placed under the containers. The central part of the repository should have kits for the localization of leaks, protective equipment and first aid equipment (an eye fountain wash).

In order to ensure a safe storage of chemical waste it is necessary to have the following separate zones preventing hazardous chemical reactions. Such zones should be marked according to the hazard class. If some waste can be classified according to several hazard classes then the most hazardous class is used:

- Explosive waste
- Toxic waste
- Flammable waste
- Oxidative waste
- Aggressive acidic waste
- Aggressive alkaline waste (bases)
- Halogenated solvents (containing chlorine, bromine, iodine or fluorine)
- Non-halogenated solvents

Liquid and solid wastes shall be stored separately. Legal entities and individuals operating in the field of waste management organize and carry out industrial control over compliance with the requirements under the existing legislation.

Chapter 12
International and Uzbek National Experience on Waste Management

12.1 International experience on waste management policy development

The main period accompanied by numerous events in the development of the waste treatment policy was the late 1980s. It was during that period that the EU Waste Incineration Directive was adopted. It was followed by the revision of the Framework Directive on waste and the adoption of the Directive on hazardous waste a couple of years later. Together, these documents became a landmark event for the control of pollution in the European Union. Since that time, many European countries have started to develop their own laws and policies to support recycling.

Austria adopted its key law on waste management in 1990. At that time Switzerland adopted a resolution on the introduction in 2000 of the ban prohibiting the storage of unsorted waste at the landfills as well as a resolution on the packaging for soft drinks. Germany adopted its law on packaging in 1989.

Germany was one of the first to encounter the overflow of landfills and planned the construction of 120 incineration plants (WIP). However, under the influence of protests coming from the "green" the government was able to build only about twenty plants by the end of the 1990s while many Federal States rejected the idea of waste incineration and began an intensive separate waste collection and recycling. The coming into force of more stringent EU standards on waste incineration led to the closure of several incineration plants and to a costly modification of the rest.

In 1994 Germany adopted the law on the recycling of products and waste management. It was aimed at minimizing the use of products unsuitable for recycling and reuse and at maximizing the use of recycled resources. After that, the Law on the closed loop economy was adopted in 1996. It was supposed to consolidate the recycling opportunities existing in the industry.

Austria also adopted two other key acts concerning packaging and biodegradable waste collection. The number of incineration plants was great in such countries as the Netherlands, Denmark, Switzerland, Sweden, and France mainly due to the problems associated with the use of dumps. No more than 13% of the total amount of municipal waste was directed to the landfills in the Netherlands, Denmark, and Switzerland. The impetus for change was not so much the lack of space for landfills but rather the concern about the dangers associated with the incineration of waste.

In the early 1990s these countries decided to either close or modify their incineration plants and support those types of processing that did not harm the interests of WIPs. In 1995 Switzerland introduced legislation on the responsibilities of the producers. Denmark implemented a strategy concerning the organization of the collection of glass bottles and waste generated during the construction and demolition of buildings. It also approved the tax revenue to be paid by WIPs to stimulate separate collection and use of recyclable materials. The Netherlands adopted a law requiring municipalities to organize a separate collection of organics with the removal from waste of the materials with a low calorific value in 1994.

Thus, the 1990s became the period of the creation and implementation of a new legislation on waste management. Northern countries became the leaders in the field in Europe. Then the European Union adopted legislative innovations. It summarized them making the necessary adjustments.

The main directions of the European policies in the field of waste handling are based on two main elements:

- Firstly, the European Commission has continued and is likely to continue to tighten the standards containing requirements for landfills and waste incineration. It also introduced the Directive on the extended producer responsibility for the disposal of their products after the completion of the products' exploitation;
- Secondly, the European Commission supported the ideas of strengthening the responsibility of the producer and implementation of waste management through the Directive on packaging, on the waste of electrotechnical and electronic goods, as well as the Directive on the vehicles that have completed their exploitation period. At present the Directive on biodegradable waste has been enacted as well.

The policy that has been pursued by the European Union recently shows that attention has been shifting from the control of environmental pollution to the wise use of resources, and sustainable consumption and production.

12.2 Municipal solid waste treatment in Germany

A few decades ago it seemed that the problem of solid waste management in Germany would be the most important problem. Experts believed that the so called "society of disposable products" had formed in Germany and that the country would soon be buried under the debris mountains.

However, Germany decided not to wait for the development of such a scenario and came up with one of the most successful solutions in the world to the problem of MSW disposal. The system «Duales System Deutschland GmbH» introduced in the whole country in 1991 allowed the Germans to avoid the environmental catastrophe.

Since that time German companies have been required by law to reduce as much as possible the size of packaging for their products. The mandatory fee for waste disposal has also been introduced. In addition, producers are required to produce either self-degradable packaging or the packaging suitable for recycling.

Experience has proved the success of this approach. The problem of waste disposal is not so acute in Germany any more.

Responsibility for waste management and environmental protection in Germany is shared among the national Government, the Federal States and local authorities. The National Ministry of Environment sets priorities, participates in the enactment of laws, oversees strategic planning, information and public relations and defines requirements for waste facilities. Each Federal State adopts its own waste management act containing supplementary regulations to the national law, e.g. concerning regional waste management concepts and rules on requirements for disposal. There is no national waste management planning in Germany. Instead, each Federal State develops a waste management plan for its area.

For waste generated by households, the Recycling Management and Waste Act assign responsibility to the local public waste disposal authorities (in most Federal States these are districts and towns). Their responsibility covers the collection and transportation of waste, measures to promote waste prevention and recovery, and planning, constructing and operating waste disposal facilities. Municipalities have more practical tasks such as providing sites for waste collection.

Germany has for over 20 years had a strategy for diverting MSW away from landfills and increasing recycling. The most important initiatives taken in order to increase MSW recycling have been:

- A long tradition for developing waste strategies on the national level, and developing waste management plans in the Federal States and in the municipalities;
- Introduction of producer responsibility for packaging already in 1991;
- In 1999, the German government committed itself to completely recover all municipal waste by 2020, so that the landfilling of municipal waste and waste treatment residues would no longer be necessary. This is an ambitious objec-

Figure 12.1 Sorting line for paper waste at the waste sorting facility. Paper sorted by type will later be pressed into bales and sent for recycling.

tive and includes, for example, recovering waste incineration residues and further developing of treatment technologies such as sorting and MBT;
- A ban on landfilling un-pretreated MSW by defining requirements to the organic content of MSW direct landfilled (maximum 5% carbon content) or maximum 18% if the waste has been pretreated. The first initiatives in relation to this ban were taken in 1993, followed up in 2001 and 2002 and fully implemented in 2005;
- Focus on the separate collection and recycling of secondary raw materials (paper and biowaste), pretreatment of mixed household waste in mechanical-biological treatment plants and dedicated incineration with the energy recovery of mixed household waste.

The latest initiative is the introduction of the so called recycling bin. It was estimated that seven kilograms per capita annually of a high grade material of metal and plastic other than packaging can additionally be material recycled.

Germany was among the first European countries to introduce policies to limit landfilling in the 1990s. Measures included schemes for collecting pack-

Figure 12.2 An example of a flat-by-flat scheme of waste collection in Uppsala, Sweden. The house owner placed two mobile containers at the side of the road. One container is filled with waste going to the incineration plant; the second containing biodegradable waste is going to be used for the production of compost or biogas.

aging waste, biowaste and waste paper separately. The result of this was that by 2001 Germany already recycled about 48% of municipal waste, whereas approximately 25% was landfilled and 22% was incinerated.

In 2010, the level of recycling had increased to 62%, landfilling was almost 0% and incineration had increased to 37%.

12.3 Municipal solid waste management in Sweden

The system of sorting and further recycling of MSW in Sweden began to operate at the end of the 20th century. Even though not that much time has passed since then it has become a routine thing for Swedes to sort household waste. Today there are containers near each house in Sweden. Each container is to be used for a specific kind of waste such as paper, glass, metal, plastic, food waste, and non-disposable waste.

These wastes are taken by special trucks to the initial collection stations. Trucks collect different types of waste on different days of the week so in the morning residents place at the side of the road the waste that is to be collected on that particular day.

It is forbidden in Sweden to throw away together with other types of waste hazardous waste that is not to be disposed of. Chemicals, batteries, aerosols, etc. are taken by residents to special waste stations located in each town where containers for such wastes are located.

Individuals living in private houses and companies pay to waste treatment plants for the MSW disposal. Residents themselves sort the waste in advance making a significant contribution to the solution of the problem of waste processing.

Sweden's example is an example of a successful combination of legislation, scientific and industrial technologies and energy saving behavior of the population. That is why it is not surprising that the Swedish model of solid waste treatment is followed by many European countries.

12.4 Waste management system in Poland

The waste management system in Poland has recently undergone a transformation. According to the amendments to the Act on Maintaining Cleanliness and Order in Municipalities (1996), from January 2012 citizens are no longer the legal owners of waste. The municipality (rather than the citizen) will choose now a company to be responsible for waste removal in its specific area. Municipalities shall ensure cleanliness and tidiness in their own area and shall create the necessary conditions to maintain it, and in particular, they shall guarantee the building, maintenance and use of one's own municipalities, or those jointly shared with others, regional installations for the processing of municipal waste, i.e. waste incineration plants. There are three options for selection of an entity to construct, maintain and operate a regional facility: Public tender under Public Procurement Law (preferred by municipalities) choice under Public Private Partnership Law and choice under Construction Works and Services Concession Law. Property owners shall pay the municipality a monthly fee for the management of municipal waste.

Pursuant to the above-mentioned Act municipalities must achieve, by 31 December 2020, in the case of municipal waste including: paper, metals, plastics, and glass – the recycling rate and preparation for reuse at the level of at least 50% by weight, and in the case of non-hazardous construction waste and demolition

Figure 12.3 Local waste station located in residential area in Poznan, Poland.

waste – the recycling rate and preparations for reuse at the level of at least 70% by weight.

This obligation results from the European Parliament and Council Directive 2008/98/EC regarding municipal sewage treatment.

In addition, in relation to the above-mentioned Act and to the European Parliament and Council Directive 1999/31/EC concerning waste landfill the target of municipalities shall be to limit biodegradable municipal waste mass going to landfill:

- by 2013 – to no more than 50% weight-wise of total biodegradable municipal waste mass going to landfill,
- by 2020 – to no more than 35% weight-wise of total biodegradable municipal waste mass going to landfill – in relation to waste mass generated in 1995.

Poland already has a number of operating energy from waste facilities with plans to build a further 12 to 14 plants. The municipal waste disposal market is worth some 5 billion Polish Zloty (€1.2 billion) and set to rise by 20% in 2015.

12.5 Waste management system in Lithuania

The waste policy in Lithuania was poorly developed at the beginning of the 1990s – many household waste streams simply did not exist, the reuse rate of packaging and organic waste was high and what was left over was dumped in hundreds of uncontrolled sites that fell short of environmental standards.

As Lithuania moved towards a market-based economy, a legislative framework for waste handling was built up, institutions were created and their responsibilities were defined, waste management strategies were developed with targets set for individual waste streams and, at the same time, measures were introduced for the continuous improvement of the system. By 2009, the waste collection system covered 80% of residents, while in 2010 this figure grew to 94%. The remaining population only has access to other forms of waste collection services (e.g. civic amenity sites).

Municipalities are the main institutions organizing municipal waste management, with the main responsibility to create effective waste management systems.

Local authorities are also responsible for reaching EU targets regarding recycling and recovery - with the exception of some waste streams (WEEE, packaging batteries and accumulation waste) which are managed by Extended Producer Responsibility schemes. They set out the terms of municipal waste collection, transport, treatment and disposal. They are also responsible for ensuring that the waste treatment installations function. In Lithuania, residents pay a monthly fixed fee

Figure 12.4 Based on the national recycling plan, at least 45% of communal waste will have to be recycled or otherwise used in 2016 in Lithuania.

for waste management. Municipalities are responsible for billing and collection of fees. Waste management is financed under the ‘polluter pays’ principle.

Municipal waste management is conducted according to the municipal waste management rules approved by the municipal council. These rules regulate rights and duties of system actors and set the conditions of municipal waste provision. The municipal councils approve municipal waste management service fees.

In Lithuania, local authorities have a relatively strict control over waste flows and a general influence over the waste management sector. Most municipalities have joined waste management cooperation structures.

Lithuania has been developing a regional municipal waste management system since 2008. Waste collection and systems of sorting and utilization were developed. Furthermore, non-compliant landfill sites have been closed and redeemed, new and modern waste disposal facilities have been constructed and green waste composting and bulk waste acceptance sites have been installed.

The disposal of waste in old, non-compliant landfills has been banned since July, 2009. In all, 612 old landfills have been closed. According to the plans, the remaining 198 non-compliant landfills should have been closed by 2013. Regional Waste Management Centers (RWCMs) were established as legal entities with the main purpose of implementing waste management tasks effectively and creating the waste management system. For non-hazardous waste, 11 regional landfills and 21 green waste composting sites have been constructed.

An extraordinary effort will be required from the Lithuanian government to fulfil the 50% recycling target by 2020, requiring a 4.5% average yearly increase in the recycling rate to be maintained until 2020. This is a huge yearly increase that will require extraordinary initiatives. Rapid establishment of recycling facilities, combined with the introduction of effective economic incentives and robust information measures, will be essential for fulfilling the target.

The long- term objectives of the Lithuanian waste policy, among others, are to encourage waste prevention, reuse, recycling (especially secondary raw materials including packaging), to minimize disposal of municipal waste, to ensure the accessibility and high quality of public municipal waste management services and to ensure municipal biodegradable waste collection and treatment.

Although currently no landfill tax is in place in Lithuania, the introduction of a landfill tax is planned as soon as alternative waste treatment facilities come into operation and the draft document for the introduction of a landfill tax has been prepared.

In order to increase recycling levels in the country, the introduction of a certification system of products and materials obtained from recycled waste is planned as well as the organization of public facing information campaigns on waste separation.

The establishment of 36 green waste composting sites (on top of the existing 21) and 9 mechanical-biological treatment facilities are planned in the coming years in Lithuania.

12.6 Italian system of food waste collection

The first attempts to organize a separate collection of food waste in Italy started in 1993 but the Law on Waste Management adopted in Italy in 1997 gave the main impetus. Under this law, local authorities were to achieve a 35% indication for the collection and recycling of secondary resources by 2003. For this reason it was necessary to collect organic waste separately.

It meant that food waste was to be given priority as this type of waste is the main component of the total amount of "free time waste" that goes into garbage cans. If food waste can be separated then other wastes will not have to be taken away as often while their ability to biodegrade in landfills will decrease dramatically. Focus on food waste can also lead to the creation of cheaper and more efficient systems of waste collection. As food waste is characterized by a high density and water content, it does not require compaction. As a result, Italians developed special microtrucks with a small capacity (3-5 sq. meters). The operating costs amounted to 10-15% of the costs for conventional trucks.

The vehicle used for waste transportation is operated by one person and serves approximately 2,000 families. It collects 3-4 tons of waste daily. Residents put waste into small plastic bags that then are placed into 6-liter waste containers next to the kitchen sinks. Then the contents of these containers are poured into 30-liter bins that can be lifted manually. Bags are made out of some transparent material so that the waste collector can verify the contents. The bag material is biodegradable so bags can decompose together with the waste.

The average indicator of food waste collection within the frame of such systems is 150-200 kg per family per year. It makes 60-80% of the total amount of food waste in trash bins. If garden waste is included into this amount then it makes up only a small part (due to a great extent to a small size of waste bags). Garden waste is mainly composed at home or is transported to the site for composting or other forms of processing.

Many Italian municipalities that have adopted this model have reached a 50% level of separate collection. Collecting food waste often allows saving money as the team of food waste collectors costs three times less than then the team collecting regular waste though it serves the same amount of families. The system provides high quality raw materials for composting (the pollution index in this case is only 2% which is significantly lower than the common rate for the collection of waste into regular home containers in Northern Europe).

12.7 Experience of handling waste in the Republic of Uzbekistan.

The urban population in the Republic of Uzbekistan is one of the main factors determining the scope of work for the collection and disposal of solid waste as well as the choice of the optimal waste neutralization method. At present the urban population keeps growing mainly due to the inflow of people from the countryside leading to an excessive density in metropolitan centers. Therefore, it is advisable to create a system in large cities that would provide a centralized collection and transportation of MSW as well as the operation of plants for the disposal and recycling of waste using waste transfer stations and heavy vehicles.

MSW has a complex multicomponent structure (Fig.12.5). Out of various methods of MSW disposal the most popular in the region is the waste disposal in landfills (dumps). Unfortunately, out of 175 MSW landfills operating in the country that occupy about 2 thousand hectares, over 90% are in poor condition. They were organized without proper measures of engineering protection. The monitoring of their environmental impact is not conducted properly. Moreover, the fleet of special vehicles cannot cope with the growing volume of waste directly affecting the timely collection and complete removal of waste.

From the environmental point of view it should be noted that the storing of MSW in such dumps results in the formation and spread of unpleasant odors.

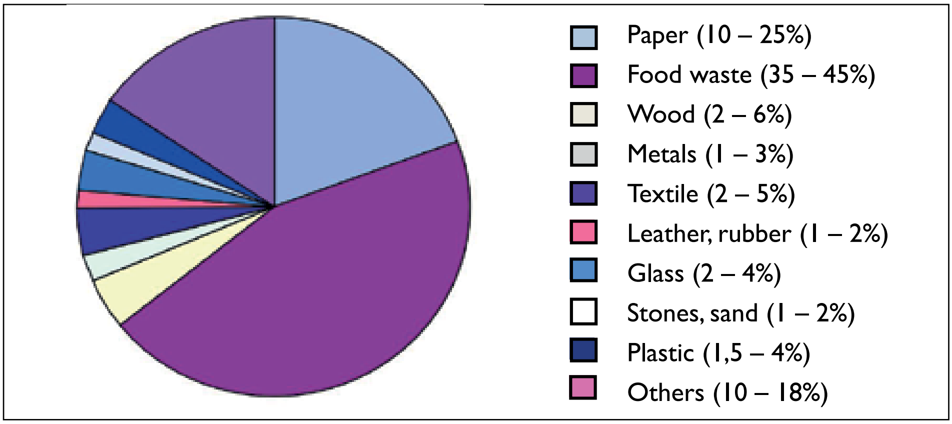

Figure 12.5 The composition of MSW in Uzbekistan (Uzbek State Committee for Nature, 2008)

These dumps along with the filtrate polluting ground water emit methane and other toxic gases into the atmosphere. All materials and components potentially useful for disposal get lost during the MSW storage and disposal.

Main drawbacks and difficulties during the collection and transportation of municipal waste include:

- lack of special vehicles transporting waste; an outdated vehicle fleet;
- insufficient supply of containers:
- illegal transportation and storage of waste by enterprises and population on unsuitable areas;
- mismatch rates for waste disposal; they are less than the cost of its removal; this eliminates the possibility to renew specialized transportation and technical means;
- increase in the number of dumps on the territory of the residential areas; the elimination of such dumps is costly.

The main problems with the storage of MSW include the following:

- operational areas of the majority of landfills are used longer than the projected project timelines;
- the majority of landfills were built without complying with the technical and sanitary safety norms;
- the vehicles used at landfills are outdated and the number of specialized vehicles is insufficient;
- there is a lack of funds for waste disposal and maintenance of landfills in proper technical condition.

Figure 12.6 A garbage truck in Tashkent equipped with a roof rack for paper and plastic waste. Photo: “Makhsustrans”.

Special attention in Uzbekistan is paid to the disposal of mercury containing lamps and appliances that are considered toxic waste. The Resolution of the Cabinet of Ministers of the Republic of Uzbekistan “On regulation of activity of the enterprises on the use and disposal of mercury containing lamps and appliances” was adopted in 2000. Special enterprises for the disposal of mercury containing lamps and appliances in Tashkent, Andijan, Fergana, Navoi, Zarafshan, and Bukhara have been built and operate at present.

A large amount of agricultural waste is generated in Uzbekistan. It includes cotton waste (guzapaya, meal, plant mass) and livestock (manure, croup residues, bedding material). Part of this waste is illegally stored at landfills.

A system of separate collection and disposal of MSW is being introduced in Uzbekistan. It is organized in accordance with the Rules for the provision of services for the collection and disposal of solid and liquid municipal waste approved by the government decree in 2014.

According the Rules, consumers are obliged to carry out the initial sorting of solid waste. Waste collection stations should be equipped with special containers for a separate collection of waste, identified with distinctive colors, inscriptions, and symbols.

The Rules prohibit the throwing of solid waste into the streets, waterways, ditches, and non-identified places and from moving vehicles onto sidewalks and the roadway part of the streets.

An important part of the Rules is the requirement for industrial enterprises to take from consumers obsolete and out of order production for further disposal at the cost of the manufacturer. The enterprises should develop a special mechanism for the acceptance of such products.

Chapter 13
Minimisation of Waste

Most modern waste strategies recognize a waste hierarchy that has the prevention and minimization of waste as its first priority. But there is a direct link between economic growth and waste production. It is a major challenge for the industry as a whole to decouple this link. The means to do this is mainly in sectors other than the waste industry itself.

Waste minimization is a process of elimination that involves reducing the amount of waste produced in society and helps to eliminate the generation of harmful and persistent wastes, supporting the efforts to promote a more sustainable society. Waste minimization involves redesigning products and/or changing societal patterns, concerning consumption and production, of waste generation, to prevent the creation of waste.

Waste prevention and minimization take place at the conception stage of a product and not when it enters into a waste treatment facility. There are different approaches to reach the aim of waste prevention and minimization. These are based on resource management – as the integrated product policy (IPP), sustainable production etc.

Within the waste industry, there are also several measures to be taken that will be driving forces in changing production and consumption behavior. Economic instruments, such as taxes or differentiated gate-fees depending on the quality of the waste, have proved especially efficient in raising the awareness of commercial waste generators.

Waste minimization refers to *strategies that are aiming to prevent waste* at source through upstream interventions.

On the *production side,* these strategies are focusing on optimizing resource and energy use and lowering toxicity levels during manufacture.

On the *consumption side,* waste minimization strategies aim to strengthen awareness and prompt environmentally conscious consumption patterns and consumer responsibility to reduce the overall levels of waste generation.

Waste incineration, whether or not it includes energy recovery, appears to be the most controversial practice with respect to its contribution to waste minimization.

Figure 13.1 Waste prevention and minimization take place before a product enters into a landfill or a waste treatment facility.

The waste industry also plays an important role in communicating with the industry and calling the industry's attention to possible improvements.

The first step in establishing a waste minimization strategy is to conduct a waste audit. The key question at the onset of a waste audit is "why is this waste present?" The environmental engineer must establish the primary cause(s) of waste generation before seeking solutions. Understanding the primary cause is critical to the success of the entire investigation. The audit should be waste-stream oriented, producing specific options for additional information or implementation. Once the causes are understood, solution options can be formulated. An efficient materials and waste trucking system that allows computation of mass balances is useful in establishing priorities. Knowing how much raw material is going into a plant and how much is ending up as waste allows deciding which plant and which waste to address first.

The first four steps of a waste audit allow generating a comprehensive set of waste management options. These should follow the hierarchy of source *reduction* first, *waste exchange* second, *recycling* third, and *treatment* last.

Innovative technology is often used to develop new processes to achieve the same products, while reducing waste. Process redesign includes alteration of existing processes by adding new unit operations or implementation of new technology to replace outmoded operations. For example, a metal manufacturer modified a process to use a two-stage abrasive cleaner and eliminated the need for a chemical cleaning bath.

Equipment changes can reduce waste generation by reducing equipment–related inefficiencies. The capital required for more efficient equipment is justified by higher productivity, reduced raw material costs, and reduced waste materials costs. Modifications to certain types of equipment can require a detailed evaluation of process characteristics. In this case, equipment vendors should be consulted for information on the applicability of equipment for a process. Many equipment changes can be very simple and inexpensive.

Disposed hazardous waste often includes two or more different wastes. Segregating materials and wastes can decrease the amount of waste to be disposed. Recyclers and waste exchangers are more receptive to wastes not contaminated by other substances. The following are good operating practices for waste segregation:

- *Prevent* hazardous wastes from *mixing* with non-hazardous wastes;
- *Isolate* hazardous wastes by contaminant;
- *Isolate* liquid wastes from solid wastes.

The following operational procedures should be used to track waste minimization efforts and target areas for improvement:

- Avoid over-purchasing;
- Accept raw materials only after inspection;
- Ensure that no containers stay in inventory longer than the specified period;
- Review raw material procurement specifications;
- Return expired materials to the supplier;
- Validate shelf-life expiration dates;
- Test outdated materials for effectiveness;
- Conduct frequent inventory checks;
- Label all containers properly;
- Set up manned stations for dispensing chemicals and collecting wastes.

Changing the *design*, composition, or specifications of end products allows fundamental changes in the manufacturing process or in the end use of raw materials. This can lead directly to waste reduction. For example, the manufacture of water-based paints instead of solvent-based paints involves no hazardous toxic solvents. In addition, the use of water-based paints reduces volatile organic emissions to the atmosphere.

Figure 13.2 The packaging of a regular table spoon can also be different including the placement of consumer useful information on the label. The more material there is in the packaging the more waste there is.

Waste exchange is a reuse function involving more than one facility. An exchange matches one industry's output to the input requirement of another. Waste exchange organizations act as brokers of hazardous materials by purchasing and transporting them as resources to another client. Waste exchanges commonly deal in solvents, oils, concentrated acids and alkalis, and catalysts. Limitations include transport distance, purity of the exchange product, and reliability of supply and demand.

Recycling techniques allow reuse of waste materials for beneficial purposes. A recycled material is used, reused, or reclaimed. Recycling through use or reuse involves returning waste material to the original process as a substitute for an input material, or to another process as an input material. Recycling through reclamation involves processing a waste for recovery of a valuable material or for regeneration. Recycling can help eliminate waste disposal costs, reduce raw material costs, and provide income from saleable waste.

It is important to note that recycling can increase a generator's risk or liability as a result of the associated material handling and management. Recycling effectiveness depends upon the ability to separate recoverable waste from other process waste.

Waste minimization can protect the environment and provide good economic and business practices. Waste minimization can improve:

- Efficient production practices. Waste minimization can achieve more output of product per unit of input of raw materials.
- Economic returns. More efficient use of products means reduced costs of purchasing new materials improving the financial performance of a company.
- Public image. The environmental profile of a company is an important part of its overall reputation and waste minimization reflects a proactive movement towards environmental protection.
- Quality of products produced. New innovation and technological practices can reduce waste generation and improve the quality of the inputs in the production phase.
- Environmental responsibility. Minimizing or eliminating waste generation makes it easier to meet targets of environmental regulations, policies, and standards. The environmental impact of waste will be reduced.

In industries, using more efficient manufacturing processes and better materials will generally reduce the production of waste. The application of waste minimization techniques has led to the development of innovative and commercially successful replacement products. Waste minimization has proven benefits to industry and the wider environment. It helps in value creation and increased quality of work.

Waste minimization often requires investment, which is usually compensated by the savings. However, waste reduction in one part of the production process may create waste production in another part.

For householders some waste minimization techniques can be applicable as well.

Appropriate amounts and sizes can be chosen when purchasing goods; buying large containers of paint for a small decorating job or buying larger amounts of food than can be consumed create unnecessary waste. Also, if a pack or can is to be thrown away, any remaining contents must be removed before the container can be recycled.

Home composting, the practice of turning kitchen and garden waste into compost can be considered waste minimization.

The resources that households use can be reduced considerably by using electricity thoughtfully (e.g. turning off lights and equipment when not needed) and by reducing the number of car journeys made. Individuals can reduce the amount of waste they create by buying fewer products and by buying products which last longer. Mending broken or worn items of clothing or equipment also contributes to minimizing household waste. Individuals can minimize their water usage, and walk or cycle to their destination rather than using their car to save fuel and cut down emissions.

In a domestic situation, the potential for minimization is often dictated by lifestyle. Some people may view it as wasteful to purchase new products solely to follow fashion trends when older products are still usable. Adults working full-time have little free time, and so may have to purchase more convenient foods that require little preparation, or prefer disposable nappies if there is a baby in the family.

The amount of waste an individual produces is a small portion of all waste produced by society, and personal waste reduction can only make a small impact on the overall waste volumes. Increased consumer awareness of the impact and power of certain purchasing decisions allows industry and individuals to change the total resource consumption. Consumers can influence manufacturers and distributors by avoiding buying products that do not have eco-labeling, which is currently not mandatory, or choosing products that minimize the use of packaging. Where reuse schemes are available, consumers can be proactive and use them.

There are financial and economic incentives which can be used to promote waste minimization:

- Research and development related to waste prevention/recovery technologies;
- Pilot projects;
- Investment in low-waste production/products;
- Consultancy services;
- Innovative solid waste recycling technologies; and
- Eco-balances, life-cycle assessments, and eco-auditing.

Financial aid and economic incentives most often take the form of subsidies, low-interest credits, cost-free consultancy services, and sureties.

Industry and related associations have taken a number of initiatives to support waste minimization, including:

- Product advertising and public relations campaigns have been carried out.
- Associations have often provided information and consultancy services to industry, or have supported research and development.
- Low-waste products have been developed.
- In some countries, voluntary agreements on the recycling of products such as end-of-use vehicles and waste tires have been supported by industry; in others, industry have initiated separate collection and recycling schemes for certain products.
- In some countries, industry have committed itself to voluntary take-back and recycling programs for certain waste streams.

However, it have resisted the imposition of waste minimization targets, for example through:

- Intensive lobbying against waste minimization legislation;
- Opposing taxes and additional fees;
- In some countries, boycotting voluntary agreements or ignoring regulations in order to gain competitive advantages (free-riding); and
- Not participating sufficiently in the minimization of packaging waste.

Examples of initiatives taken by the *waste disposal industry* to support waste minimization included:

- Promotion of recycling technologies (recycling measures were generally reported to receive more support than waste prevention activities);
- Participation in consultations on separate collection;
- Implementation of Environmental Management Systems; and
- Participation in pilot projects aimed at the collection and recycling of waste streams.

Consumers and private households have also taken various initiatives to support waste minimization. Examples included:

- A high rate of acceptance of existing recycling facilities and curbside collection programs;
- Home composting; and
- In some countries, support for low-waste products.

Consumers and private households have hindered waste minimization through:

- Reacting to unpopular landfill disposal fees by illegally dumping household waste;
- Rejecting user-pays programs;
- Giving insufficient support to separate collection systems; and
- Continuing to buy over-packaged goods.

Chapter 14
Materials Flow Analysis

14.1 Material flow analysis approach

Material Flow Analysis (MFA) is a systematic assessment of flows and stocks of resources within a system defined in space and time. It connects the sources and final sinks of resources via intermediate processes. MFA is becoming an important tool within the field of industrial ecology and environmental management to track the pollutants or resources in society. Moreover, MFA is considered as a base to develop the Life Cycle Assessment (LCA) of products and processes within a system.

The term MFA designates a family of tools based on the materials balance principle, encompassing a variety of analytical approaches and measurement tools at different levels of detail and completeness. These tools range in scope from economy-wide to substance or product-specific analysis, and input-output analysis. Each type of analysis is associated with material flow accounts or other measurement tools, and can be used to derive various types of indicators.

A material flow study can cover any set of materials at various levels of detail, from the complete collection of all resources and products flowing through a system, to groups of materials at various levels of detail, or to specific products. MFA can also be applied to specific materials or even single chemical elements of particular concern (e.g. in terms of the environmental implications of their use, or economic or trade implications).

MFA uses the principle of mass balancing to study how materials and energy flow through the economy and the environment within countries and among countries.

The principle of mass balancing is founded on the first law of thermodynamics (called the law of conservation of matter), which states that matter (mass, energy) is neither created nor destroyed by any physical process.

This leads to the following accounting identity: natural resource extraction + imports = residual output + exports + net addition to man-made stocks.

Material flow *accounts* (MFAcc) are the MFA's basic measurement tool because they provide the structure to the information needed to carry out the ma-

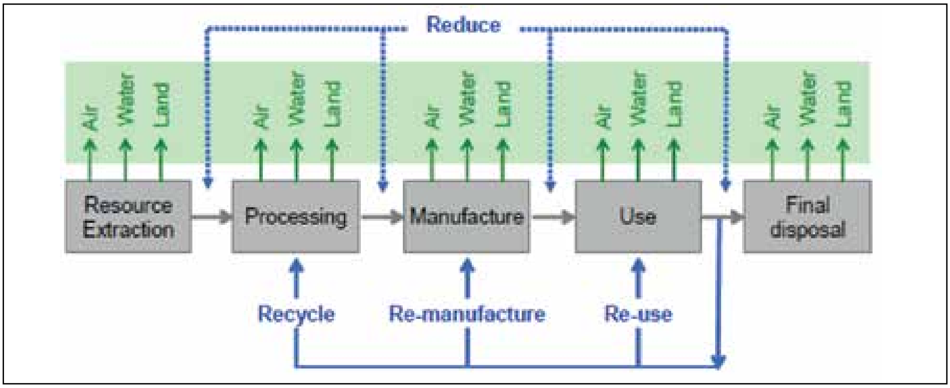

Figure 14.1 Flows of materials through the commercial life-cycle

terial flow analysis. They form the basis for many types of analysis, including the calculation of various types of indicators. MFAcc are a special application of physical flow accounts as described in the System of Integrated Environmental Economic Accounting (SEEA).

The growing use of raw materials over the past decades has been accompanied everywhere by an increased production of waste, representing a potential loss to the economy of valuable material and energy resources. Increasing the efficiency with which materials are managed over their entire life cycle therefore is a vital element of improving resource productivity and safeguarding environmental quality. In line with the principle of the 3Rs (Reduce, Reuse, Recycle), consistent recycling of used materials helps prevent waste of materials, including energy, and reduce releases to nature (Fig. 14.2).

Material flow *indicators* are important for measuring progress with resource productivity and materials use, and for communicating the results of material flow studies to a non-expert audience (general public, high-level decision makers, policy analysts, etc.).

Material flow indicators can show the level of actual recycling and reuse, and the potential of current material flows for being recycled in future. Indicators include the indicator reflecting the (potential) share of reused goods in material consumption, the indicator of the (potential) use rate of recovered used products, the (potential) material use efficiency, the (potential) material use time, the (potential) recovery rate of used products.

MFA helps identify the inefficient use of natural resources, energy and materials in process chains or the economy at large that would go undetected in conventional economic or environmental monitoring systems. It achieves this by

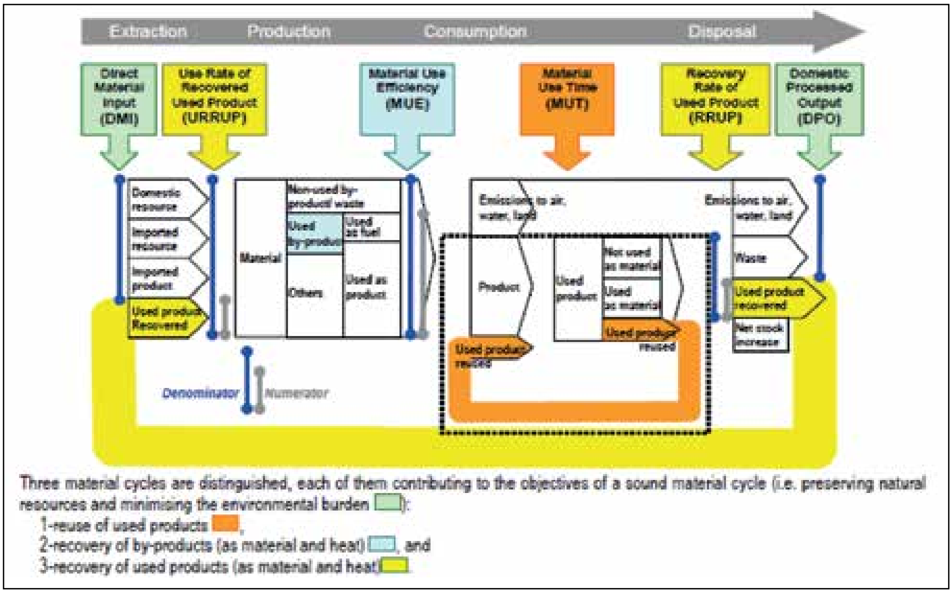

Figure 14.2 Waste and recycling indicators derived from MFA. (Source: Hashimoto and Moriguchi,2004)

Box 14.1. Questions addressed by material flow indicators

What are the material requirements of an activity or an economy?
Which and how much material resources are used for what purposes? How much is non-renewable vs. renewable, primary raw material vs. secondary raw material? How does this change over time? How does this relate to available stocks of natural resources?
How dependent is an activity or an economy on external material inputs or external material markets?
How much stems from own vs. foreign territory (resilience, dependence, supply security)? How does this change over time? To what extent do international material flows shift between countries and world regions? How does this relate to foreign outsourcing, international trade and market prices for materials?
How efficiently are material resources being used?
Are valuable resources wasted unnecessarily? What is the level of coupling or decoupling of economic growth, resource use and environmental pressures? How does this relate to the productivity of the economy, of industrial sectors?
What is the potential for improving resource productivity?
What opportunities arise from improved materials management and resource policy? How does this relate to labor and capital productivity?
What are the main environmental risks and pressures associated with material resource use?
Where in the material cycle (extraction, processing, consumption, disposal) are these risks located and how do they change over time?
What are the main environmental consequences of international material flows?
How do these consequences change over time and shift between countries and world regions?

using already available production, consumption and trade data in combination with environment statistics, and by improving modelling capacities.

14.2 Life cycle assessment of waste flows

Specific tools, such as life cycle assessments (LCA), are extremely useful when we consider the overall impact of a product and assess its sustainability. LCA measures inputs and outputs, from the mining of the resources to final disposal. It can take into consideration environmental benefits and costs and include the technical, social and economic implications of different waste management options.

LCA has been used to an increasing extent by environmental groups or as marketing initiatives. LCA can be used to compare comparative acceptability of consumer products, such as disposable nappies versus cotton nappies, plastic drinks containers versus glass. But it can also be used in more complex situations such as when evaluating the setting up of a local waste management system in order to determine which treatment methods to rely on. Any LCA will, of course, depend on the local circumstances and the results may vary from one region to another.

LCA can be defined as a method studying environmental aspects and potential impact of products or a process during its whole life cycle starting with the extraction of raw materials and production processes up to the final placement in the

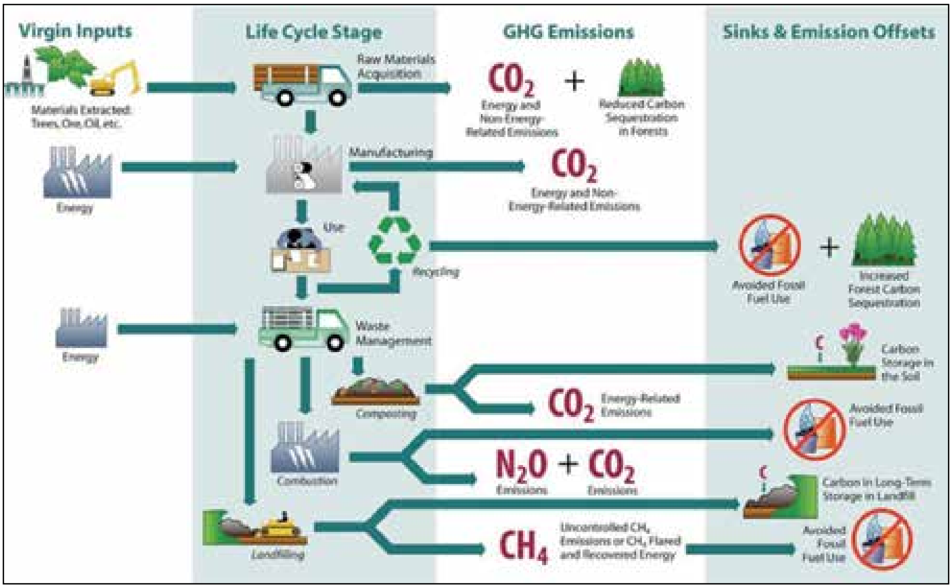

Figure 14.3 The scheme of the resource life cycle

environment. Figure 14.3 schematically shows the concept of carrying out LCA as a system with incoming flows: natural resources and energy and outgoing flows: emissions and products. A complex integrated approach to the carrying out of LCA guarantees account and assessment of all emissions and impacts of production and processes on the environment during the whole period of their existence in the technosphere. Such a wide analytical coverage ensures the inclusion into the assessment of both direct and indirect effects of the products on the environment.

Recently interest in LCA has grown. More and more state bodies, companies and scientific and research institutes are applying LCA in the decision making processes and for the development of the plans for the expansion of the production of specific products and whole sectors of economy. At the same time an optimal structure for the carrying out of LCA was developed to ensure the overall recognition of the LCA results, the improvement of their quality and transparency, the provision of comparability of the results of different analyses and limitations on the possibility of manipulating. International standards ISO 14040 contains main requirements to the carrying out of LCA.

LCA consists of four phases, each of which plays a significant role in the process of this assessment (Fig. 14.4). Defining the purpose of LCA means to formulate the objectives of planned studies, reasons for the carrying out, and the possibility to use the received results. The scope of LCA that includes the definition of the boundaries of the studied system and level of detail depends on the object and purpose of the research goal. The depth and width of LCA can vary greatly depending on the goals of a particular assessment. The key element in determining the sphere of LCA application is the choice of the research object, that is, a functional unit. The functional unit is a unit of a product or service the impact of which will be evaluated and compared. When reviewing the waste management system the functional unit is a certain amount of a specific waste

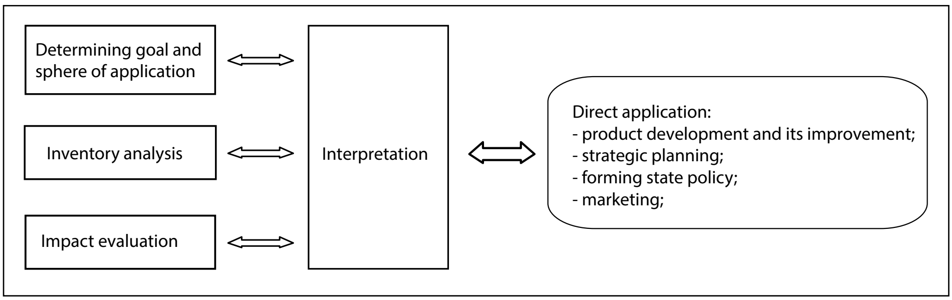

Figure 14.4 Stages of LCA

composition during the prescribed period of the system functioning under specified conditions.

The inventory analysis of the life cycle is the inventory of input/output streams of the studied system and involves the collection of data required for the achievement of the specific goals of the study. The data including the information about the amount of the consumed energy and materials, the amount of pollutants released into the environment, and the generation of waste are determined for each process throughout the whole life cycle of the studied functional unit.

The goal of LCA is the determination of the importance of potential impacts on the environment on the basis of the inventory analysis data. The assessment of the impact of life cycle is the most complicated methodological stage of LCA. The complexity of the impact assessment is the need to compare between diverse environmental impacts that require the generalization of the inventoried flows of substances or energy with similar environmental impacts in the impact category.

When interpreting the results of the life cycle the findings and/or results of the impact assessment are summed up and considered as a basis for conclusions, recommendations and decision making in accordance with the set objectives and area of distribution. The interpretation phase may involve an interactive process of reviewing and updating the area of LCA study as well as the character and quality of data collected in accordance with the set goal.

The assessment of the life cycle of the waste management systems can be carried out in two directions. One of the LCA areas is the evaluation of the potential environmental impact of different technologies of waste disposal in order to evaluate its whole environmental performance and/or identification of processes and stages requiring optimization. Another direction is the analysis of different alternative waste management systems to achieve the goals of sustainable development and the determination of the direction for the development of environmental strategies. LCA allows to compare different technologies, techniques, programs of waste management and identify the most effective ones for these conditions ensuring the minimum impact on the environment and man's health. The use of LCA in such complex systems as the waste management system is linked to specific problems and peculiarities such as the determining of the boundaries of the production system, of the functional unit; the consideration of the prevented impact; the time aspect; the carbon balance; the evaluation of the impact on the environment.

The system of waste management can be seen as a service that performs various functions for society. However, when assessing the life cycle of waste management systems it is difficult to define the term "cradle" or "grave" as the waste consists of different types of products and the inclusion in the analysis of the resource extraction for all types of products turned waste is impossible; the "cradle" should comply with the "grave" of the products. Therefore, when assessing the life cycle of waste management systems "initial" processes are not considered and are excluded from the analysis while the waste is treated without input streams and the phase "cradle" starts with the process of waste collection. During its life cycle the product undergoes a number of successive processes. Input and output flows of all these processes related to a specific product are taken into account when carrying out LCA. Waste LCA includes a certain combination of processes participating in the disposal of waste consisting of a variety of products.

When assessing the life cycle of waste management systems it is also difficult to determine the time limits of the product system. First of all, it concerns the landfills which are an inseparable element of any waste management system. All waste treatment processes are accompanied by the formation of waste that can't be utilized. The only means to remove it is to landfill it. For instance, incineration of waste leads to the generation of ash and slag while sorting leads to the generation of substandard fractions. Landfills continue to be the sources of emissions into the environment for quite a long time, as long as it takes for the landfill material to decompose. It is very difficult to calculate the exact duration of the processes in the landfill body which are the cause of emissions. Therefore, when carrying out LCA it is possible to ignore the emissions subjectively after a certain period of time or the landfill should be treated as a completely stabilized system only after a lapse of calculated contingent years excluding from the calculations all the emissions before the final assimilation of the landfill material into the environment.

The assessment of environmental impact aims at analyzing the magnitude and significance of potential environmental impacts of the assessed product system. When carrying out LCA it is, as a rule, unknown where and when all emissions will occur. This is the reason why LCA analyses the potential impact rather than the existing one. The situation is even further complicated during the landfill assessment when the impact is prolonged. The number of emissions cannot be measured, they can only be simulated. Thus, it turns out that the LCA of landfills can assess only potential emissions rather than the real ones.

The assessment of life cycle is an effective analytical tool used to compare different scenarios and technologies of waste disposal and finds a wide practical application in waste management.

In spite of a wide use of LCA as a method of complete assessment of technologies and processes as well as the decision support like any other method LCA has got a number of limitations:

- Comprehensiveness of coverage of the product system aspects. The main characteristic of LCA is the coverage of all phases of life cycle and all potential impacts on the environment which is both an advantage of the method and a limitation. A wide coverage for the LCA analysis of the product is possible only through the simplification of other aspects.
- Linear modeling. LCA usually considers all processes (economic and environmental) as linear and unchangeable over time.
- The problem of assessment of all categories of impact. LCA evaluates only those criteria which are stated in the research methodology and, consequently, it is not a complete assessment of all environmental aspects of the studied product system.
- Availability of data. Despite the fact that databases were created in many developed countries and the database format was standardized, in fact, a lot of data is often out of date, inaccurate, and incomparable.
- Assessment of the impact on the environment. There are no common methodologies of consistent and accurate alignment of the inventory data with the specific potential environmental impacts.
- LCA cannot replace the process of decision making itself. One cannot say "the assessment of life cycle has shown that the decision must be made" but one can say "the decision was made on the basis of the assessment of life cycle and other evidence".

The LCA specificity is that there is a need to work with large amounts of data resulting in significant time and labor costs. Due to the absence in the countries with economies in transition of quality statistical databases on the effects of the most widely used technologies that meet the research requirements as well as LCA software the implementation of LCA is quite complicated.

In terms of features typical of post-Soviet countries and due to a low level of development of environmental waste management and the lack of practical application of various waste management technologies one should keep in mind the problems of availability and lack of comprehensive and reliable data for the inventory analysis. This problem is solved only by the use of foreign data of the inventory analysis which will not always correspond to reality due to specific local conditions and standards.

However, it should be noted that in spite of certain limitations this method is an important analytical tool to choose among different technologies, scenarios having reliability and credibility of the results. Therefore, it is possible to talk about the huge potential for the development and application of LCA in countries with economies in transition.

There are various methods for collecting *data*. Data can be collected from existing sources, by conducting special surveys, by taking measurements, or through regular reporting mechanisms. The information on most socioeconomic and physical condition indicators (such as the administrative area, population, the number of households, and commercial/business establishments) normally is available from the municipal departments responsible for urban planning and public works. Therefore, such information should be collected from those agencies and should be frequently updated.

Waste characterization surveys, should be carried out to collect information on generation rates, physical composition, bulk density, and storage indicators. Physical and chemical characteristics of the wastes, such as calorific value and chemical composition, are determined through laboratory analyses. If these types of data are required, it is important to determine the capabilities and experience of the laboratories such that reliable data are obtained.

Information on the indicators for collection, transport, processing, resource recovery, final disposal, and administration can be obtained from the respective services through a regular reporting system.

14.3 Waste management computer models

There are several tools for environmental systems analysis of waste management. For example, ORWARE (ORganic WAste REsearch) is a computer-based model for calculation of substance flows, environmental impacts and costs of waste management. It was first developed for systems analysis of organic waste management, hence the acronym ORWARE but now covers inorganic fractions in municipal waste as well. ORWARE consists of a number of separate sub-models, which may be combined to design a waste management system for, e.g., a city, a municipality or a company. All process sub-models in ORWARE calculate the turnover of materials, energy and financial resources in the process (Fig. 14.5):

Processes within the waste management system are e.g. waste collection, anaerobic digestion or landfill disposal. Materials turnover is characterized by the supply of waste materials and process chemicals and by the output of products, secondary wastes, and emissions to air, water and soil. Energy turnover is use of different energy carriers such as electricity, coal, oil or heat, and recovery of e.g. heat, electricity, hydrogen or biogas. The financial turnover is defined as costs and revenues of individual processes. A number of sub-models may be combined to a complete waste management system in any city or municipality (or other system boundary).

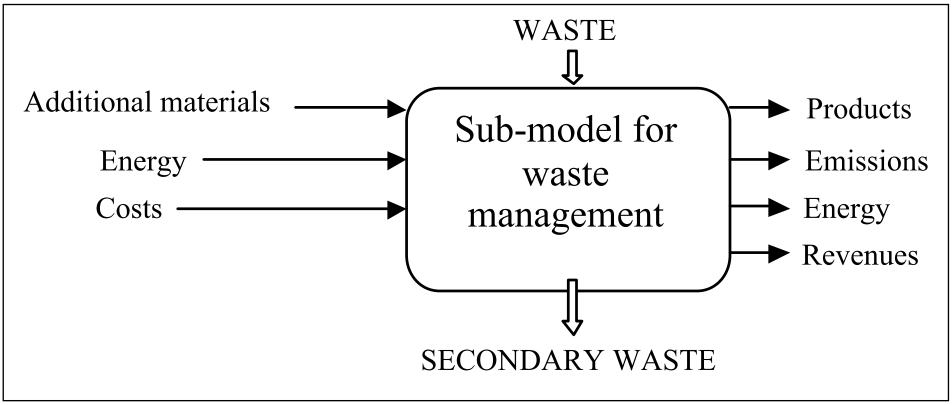

Figure 14.5 Conceptual design of a process sub-model in ORWARE

STAN (subSTance flow ANalysis) is a free software that supports performing material flow analysis (MFA) according to the Austrian standard ÖNORM S 2096 (Material flow analysis - Application in waste management) under consideration of data uncertainties. The main idea behind STAN is the combination of all necessary features of a MFA in one software product: graphical modelling, data management, calculations and graphical presentation of the results. The benefits of the application of STAN are demonstrated on the example of a fictitious waste management company.

STAN is often used simply for displaying mass flows of goods and substances as Sankey arrows. This offers the advantage that the largest flows of materials can be recognized immediately.

Due to measurement uncertainties contradictions in input data are inevitable. Often it is not clear how to handle these inconsistent data. STAN offers the possibility to reconcile measured values in order to find the best fitting ones without guessing. Gross errors in input data are detected by statistical tests. In this way possible contradictions in given data are resolved which is prerequisite for calculating the values of unknown variables and their corresponding uncertainties.

A wide spread use of STAN offers the opportunity to describe and analyze arbitrary systems with a standardized method. It can be instrumental as a base for modelling material flows for the assessment of the economic, resource and environmental value of materials.

Chapter 15
Recycling of Waste and Materials Recovery

15.1 Recycling of municipal solid waste (MSW) for materials recovery

Recycling of waste with reuse of reclaimable materials is a decisive technique that helps to reduce the total amount of waste generation and the necessity to process them, which is the main target of the modern waste management system.

Many materials contained in waste retain their feedstock value and/or possess qualities enabling their use as raw materials for making new products or substituting scarce materials. For these possibilities to be utilized, these materials must be separated from the waste flow and processed individually. For reuse, these materials must meet certain purity requirements. Both separation of valuable materials from the flow of waste and their processing in the form of relatively pure fractions for further industrial use must start with waste *sorting*. Separation/ sorting of waste can be performed at source, i.e. by the waste generator, and/or after its collection by special industrial facilities. If the required conditions are provided, the waste generator can save the money otherwise to be spent on paying waste disposal fee. Withal, the town (settlement) can cut the territory of the landfill due to smaller waste quantities and in some cases can even collect revenue from selling secondary raw materials.

Of all collected waste, separate collection is usually arranged for the following categories of waste to be further processed before reuse:

- Waste paper
- Glass scrap
- (lightweight) packaging materials
- Used automobile tyres.

Different waste treatment processes and combinations of techniques are employed. Each treatment stage aims at separating material fractions to be sent directly to recycling. Therefore the main purpose is removal of contaminants and foreign substances that can hinder recycling or make it impossible. For this, sorting and separation machinery can be used. The rate of waste recycling depends on the target quality of the fraction to be recycled (e.g., separation of several sorts of

Figure 15.1 Separate collection of waste in a residential sector in Uppsala (Sweden). Separation of waste into fractions (organic waste, plastic, paper and cardboard, glass, metal) starts in the kitchen and is done with simple accumulation containers devices. Large containers for separate collection of garbage are placed near houses

paper into fractions containing different percentage of foreign paper substances), which in turn is determined by the market demand, the existing prices and the expected revenue from selling different sorts of paper.

15.2 Waste paper

The environmental *benefits* of paper recycling are many. Paper recycling:

- Reduces greenhouse gas emissions that can contribute to climate change by avoiding methane emissions and reducing energy required for a number of paper products;
- Extends the fiber supply and contributes to carbon sequestration;
- Saves considerable landfill space;
- Reduces energy and water consumption;
- Decreases the need for disposal (i.e., landfill or incineration which decreases the amount of CO_2 produced).

On the other hand, when trees are harvested for papermaking, carbon is released, generally in the form of carbon dioxide. When the rate of carbon absorption exceeds the rate of release, carbon is said to be "sequestered." This carbon sequestration reduces greenhouse gas concentrations by removing carbon dioxide from the atmosphere.

Box 15.1. Facts: Recycling one ton of paper would:

Save enough energy to power the average European home for six months.
Save 30,000 liters of water.
Save 3.0 cubic meters of landfill space.
Reduce greenhouse gas emissions by one metric ton of carbon equivalent (MTCE).

Paper recovery in Europe has a long history and has grown into a mature organization. In 2004 the paper recycling rate in Europe was 54.6% or 45.5 million short tons (41.3 Mt). The recycling rate in Europe reached 64.5% in 2007, leaving the industry on track to meeting its voluntary target of 66% by 2010.

For quality high-benefit material to be obtained, household waste paper must be sorted at source if it is possible, and stored separately, especially from wet, oiled and/or biological wastes. The simplest collection pattern is mixed collection of printed and non-printed waste paper. Separation of the mentioned fractions is not widely used yet, but is the best means to ensure selling collected waste paper at higher prices and obtaining paper of higher quality.

A good method of collecting waste paper from households is delivery to the centrally located accumulation containers. Special modifications of the charging

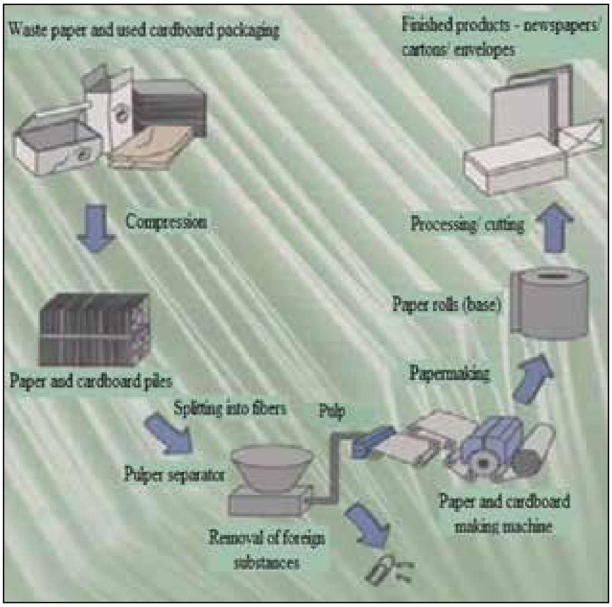

Figure 15.2 The process scheme of recycling waste paper for materials (paper) recovery.

opening reduce the amount of unwanted materials and potential contaminants contained in the collected waste. Collection of waste paper (thrown away in different containers or left in piles at the curbside) from the source of generation can also be organized. Collection of piled waste paper or paper contained in specially labeled accumulation containers is most suitable for separate collection of printed and non-printed paper.

Waste paper collection and transportation costs range from 60 to 150 Euros per ton in Europe.

15.3 Glass scrap

Glass making is a highly energy intensive process, which produces negative impact mainly on the air quality. Reuse of recycled glass, which constitutes on average about 8% of household wastes, instead of making it from scratch reduces energy consumption by 20%.

Recyclable glass includes bottles, jars and other types of glassware. This type of waste is usually collected in special containers (separate for coloured and uncoloured glass) placed near supermarkets, parking lots, inside residential sectors. Such collection system is widely spread in many countries. Some countries (e.g. Sweden) have achieved a fairly high rate of glass collection (92%). But due to constantly growing volume of imported products in glass tare it is difficult to assess the actual collection rate.

Thanks to its physical and chemical properties, glass is a highly recyclable material. Glass recycling process requires a minimum content of impurities; therefore collected glass must be as pure as possible. Glass colour is an important factor for sales level. Even relatively pure glass is checked prior to recycling. Large foreign particulates are removed either manually or mechanically. Besides, it should be noted that whole bottles are easier to sort. But glass waste sent to recycling is usually broken, which virtually eliminates the possibility of sorting.

The main contaminants that must be removed from waste glass prior to recycling are:

- Inorganic substances (ceramics, dishware, metals, bricks, stones, etc.);
- Organic substances (food remains, labels, corks, paper packaging, chips, etc.);
- Other types of glass such as crystal, window glass.

To facilitate high quality and economically beneficial recycling of household glass scrap, it is important to arrange its separate collection by colour at source. Sorting

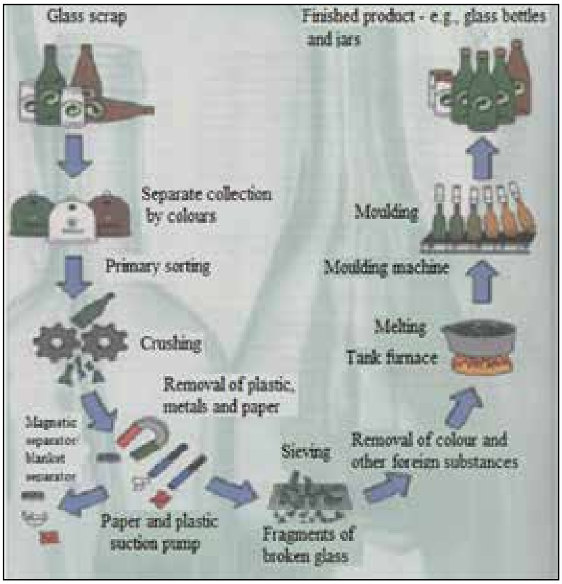

Figure 15.3 Glass recycling scheme.

is usually done for the following colours: green, brown (or mixed colours) and white or transparent. A separate container must be provided for each of the colours.

If the requirements set for the quality of recyclable glass are low, or the recycled glass is to be used for making products with no specific requirements, glass scrap can be collected in mixed form. But glass not belonging to glassware (e.g., plate glass, reinforced glass, etc.) must be eliminated from glass scrap collected by households.

The quality of glass scrap depends on the awareness level of the population and its willingness to participate in waste collection. The frequency of emptying containers, transportation and storing places are also the factors to influence the recyclability of collected glass scrap.

The glass industry derives double benefits from glass recycling – first, from substituting virgin raw materials, and second, from reducing the energy consumption for glass melting. But the required precondition for this is ensuring colour and material uniformity of glass and separate collection of different sorts of glass (glassware/ plate glass). Networks of glassware collection centres can be of significant help for organizing pure and sufficient in volume collection. Glass scrap collection costs vary from 50 to 100 euros per ton in Europe.

A deposit-return collection system must be implemented for deposit paid glassware.

15.4 Packaging waste

Lightweight packaging materials accumulated by households are usually collected in a mixed form and left for disposal in plastic bags or accumulation containers. Separate collection of metallic packaging is organized in rare cases. Depending on the market conditions and the existing sorting requirements, packaging waste is divided into the following fractions: tin, aluminium, cardboard beverages packaging, layered cardboard and paper packaging, coloured film, transparent film, other sorts of film, plastic containers, bulky plastic products, mixed plastics, other metals including non-recyclable.

The sorting technologies can be very different (e.g., in Germany there are over 2,000 waste sorting facilities). Modern sorting equipment is characterized by a high automation level; almost three quarters of the sorting facilities in Germany are equipped with the NIR system (Near-Infrared Spectroscopic Characterization) performing an automatic identification of materials during sorting. Thus, for example, this system can differentiate between different sorts of plastic by their polymer structure and perform corresponding separation procedures based on this differentiation. Due to this technology we have managed to start separating polyethylene, polypropylene, polyethylene terephthalate (PET) and polystyrene. Near-Infrared Spectroscopic Characterization permits glass sorting by colour. This technology also allows to position different sorts of glass on the sorting conveyor. This data is transferred to the processing unit which regulates waste separation at various sections of the sorting conveyor, e.g., by means of blast holes or shutters.

Modern automated sorting technologies have advanced so much that even unseparated at source packaging mixture can be automatically sorted into recyclable fractions.

15.5 Plastic

Municipal solid waste (MSW) is the greatest source of plastic waste. In European Union countries the average annual generation rate of plastic waste approximates 40 kg per capita.

Plastic is an organic polymeric material that can be moulded or pressure deformed when heated. Depending on its thermostability, plastic is divided into thermoplastic (it softens when heated and therefore is recyclable) and thermosetting plastic (it does not soften when heated and must be disposed of). Thermoplastics constitute about 85% of all the plastic sold.

The bulk of plastic waste consists of polyethylene-based waste (high- and low-pressure) and polypropylene. The total weight of the mentioned wastes

Figure 15.4 Collected, packed and prepared for recycling PET tare waste.

amounts to 50% of all municipal plastic waste. Polyethylene terephthalate is the third greatest source of plastic waste (10-15%).

The main sources of plastic MSW are packaging, different domestic appliances, furniture clothing, footwear and toys. The bulk of plastic (both hard and soft) comes from packaging. The majority of hard plastic packaging is recycled, while soft plastic packaging is not recycled and remains a part of mixed waste. To increase the value of extracted materials and recycling it is necessary to reduce the content of foreign particulates. Therefore, plastic packaging must be devoid of foreign substances (metallic lids, other non-plastic materials). Plastic recycling not only allows to reduce the quantity of landfilled and incinerated MSW, but also to save the energy required for producing packaging from virgin materials.

The use of PET tare has been steadily increasing in the recent years (especially for beverage packaging). This sort of plastic can be both recycled and reused. Using recycled PET reduces energy consumption for the production of virgin PET polymer by 62-92%. For recycled high- and low-pressure polyethylene energy savings range from 38 to 77% correspondingly. Yet, there is a range of problems and hardships concerning plastic collection and recycling:

- It is difficult to persuade manufacturers that virgin and recycled plastics are equal in quality;
- Plastic can be recycled a limited number of times; besides, recycled plastic can practically never be used for making food packaging;
- Plastic is a fairly lightweight material and therefore costly to collect and sort;
- Automatic sorting of plastic is not always efficient and is costly;
- Recycled plastic is often more expensive than virgin plastic.

To improve the quality of packaging recycling, the population should be informed on the following recommendations:

- Deposit paid packaging must be collected and returned separately;
- Non-food packaging must be collected separately (e.g., packaging from paint, domestic chemicals, drugs);
- All recyclable packaging must be emptied and devoid of foreign matters (lids, corks, etc.) prior to disposal;
- Packaging should be sorted by material types, e.g. transparent and coloured glass, hard and soft plastics, PET;
- If containers are filled, waste must not be left nearby.

Plastic extracted from waste flows can and usually is recycled for reuse in polymeric materials production (for example, in Germany around 40% of collected plastic is used for this purpose). It can also be utilized as a filler or restoration material or for energy generation. For reuse, plastic must be cleaned, melted and crushed into granulated material.

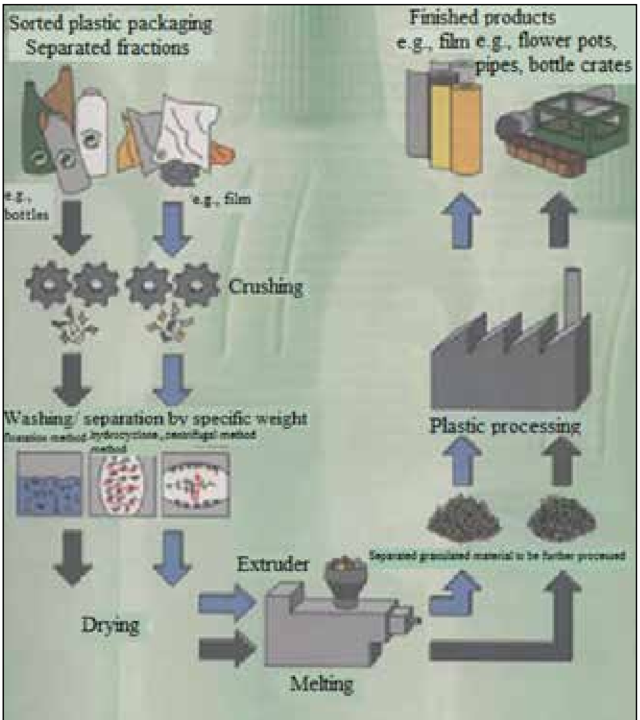

Figure 15.5 The scheme of recycling sorted and unsorted plastic.

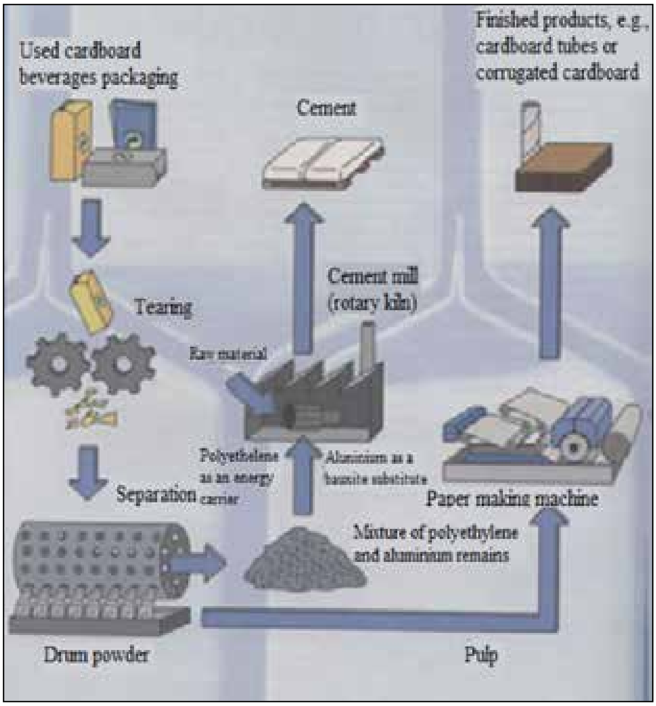

Figure 15.6 Tetra-pak recycling scheme

15.6 Cardboard beverages packaging (Tetra pak)

Cardboard beverages packaging is also recyclable. For this purpose cardboard is crushed and then dissolved in the pulper. During the process of swelling, paper fibers come off the polyethylene film and the aluminium foil of the cardboard packaging. The pulp is purified and can be reused for making paper.

Secondary raw materials obtained by such method can be used for making high-quality products, cardboard articles, kraft paper and hygienic paper. Polyethylene and aluminium obtained in this process can serve as a feedstock for plastic and aluminium production. Besides, aluminium can be utilized in place of bauxite foe cement making.

15.7 Metal packaging

Whereas plastic packaging may cause difficulties due to the disparate nature and need to separate it into its different types – metal packaging recycling is simpler. As the ferrous and non ferrous components can be separated using magnets one large problem of identification is solved. Whilst beverage cans remain the

Box 15.2 Steel facts and figures:

- All steel cans are 100% recyclable
- Two-thirds of all cans on supermarkets shelves are made from steel
- Recycling 1 ton of steel scrap saves 80% of the CO2 emissions produced when making steel from iron ore
- Recycling seven steel cans saves enough energy to power a 60-watt light bulb for 26 hours

most popular choice for collection by local authorities - aerosol cans and aluminium foil are accepted by many. Approximately 85% of aerosols are made from tin-plated steel, and the rest from high-grade aluminium.

Steel cans have a very thin layer of tin that protects the surface of the can. The average weight of this tin coating has decreased by 40% over the last 20 years and the average steel can now only weighs 22g compared to 34g twenty years ago. Although this has given great resource savings, throwing cans away still wastes valuable resources and adds to the amount of waste that has to be landfilled. As local authorities recognize benefits to be gained from including steel cans in their multi-material curbside collection schemes, so recycling rates have risen. But plenty of steel cans are still going to landfill, this despite the fact that owing to the high price paid for steel, recycling collections can often be made at zero cost to the collector.

Every ton of steel packaging recycled makes the following environmental savings:

- 1.5 tons of iron ore
- 0.5 tons of coal
- 40% of the water required in production
- 75% of the energy needed to make steel from virgin material

Almost 75% of all canned drinks sold in EU are packaged in aluminium. *Aluminium cans* are recycled into new aluminium cans. Used beverage cans are normally back on supermarket shelves as new beverage cans in 6-8 weeks. With a growing percentage of cans made from aluminium, because of its lightweight qualities, this ensures a healthy market for aluminium can recycling.

Aluminium foil and aluminium cans are made of different alloys and must therefore be collected separately. Most recycled aluminium foil is used to make cast components for the automotive industry, such as cylinder heads and engine blocks.

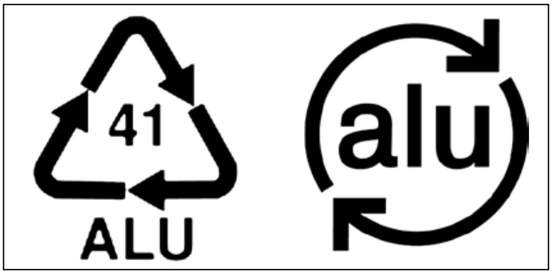

Figure 15.7 Labeling on aluminium packaging indicates it can be recycled.

When washed, foil milk bottle tops, tops of cartons, baking and freezing trays, kitchen foil, cigarette and tobacco foil (without the backing paper) are all suitable for collection. Metal coated plastic film, which is often used for crisp and snack packets, looks like aluminium but cannot be recycled.

- Aluminium beverage cans are usually recycled by the following method:
- Cans are first divided from municipal waste, usually through an eddy current separator, and cut into small, equally sized pieces to lessen the volume and make it easier for the machines that separate them.
- Pieces are cleaned chemically/mechanically, and blocked to minimize oxidation losses when melted. (The surface of aluminium readily oxidizes back into aluminium oxide when exposed to oxygen).
- Blocks are loaded into the furnace and heated to 750 °C ± 100 °C to produce molten aluminium.

Dross is removed and the dissolved hydrogen is degassed. (Molten aluminium readily disassociates hydrogen from water vapor and hydrocarbon contaminants.)

Figure 15.8 Used aluminium cans compressed and prepared for remelting.

Box 15.3 Recycling 1kg of aluminium saves:

- up to 6kg of bauxite,
- 4 kg of chemical products and
- 14 kWh of electricity.

A recycled aluminium can saves enough energy to run a television for three hours

This is typically done with chlorine and nitrogen gas. Hexachloroethane tablets are normally used as the source for chlorine. Ammonium perchlorate can also be used, as it decomposes mainly into chlorine, nitrogen, and oxygen when heated.

Samples are taken for spectroscopic analysis. Depending on the final product desired, high purity aluminium, copper, zinc, manganese, silicon, and/or magnesium is added to alter the molten composition to the proper alloy specification.

The furnace is tapped, the molten aluminium poured out, and the process is repeated again for the next batch. Depending on the end product it may be cast into ingots, billets, or rods, formed into large slabs for rolling, atomized into powder, sent to an extruder, or transported in its molten state to manufacturing facilities for further processing.

Recycling aluminium requires only 5% of the energy and produces only 5% of the CO_2 emissions as compared with primary production and reduces the waste going to landfill. Aluminium can be recycled indefinitely, as reprocessing does not damage its structure. Aluminium is also the most cost-effective material to recycle.

Recycled aluminium uses 5% of the energy that would be needed to create a comparable amount from raw materials. The benefit with respect to emissions of carbon dioxide depends on the type of energy used. Electrolysis can be done using electricity from non-fossil-fuel sources, such as nuclear, geothermal, hydroelectric, or solar. Aluminium production is attracted to sources of cheap electricity. Canada, Brazil, Norway, and Venezuela have 61 to 99% hydroelectric power, and are major aluminium producers.

15.8 Recycling of scrap rubber tyres

Pollution of the environment with polymeric waste results from the constantly growing assortment and quality of products containing polymeric materials. The most important multi-ton waste nowadays is scrap tyres. The recycling rate of tyres is currently very low.

Figure 15.9 Disposal of tyres on a mobile shredding facility on a MSW landfill in Sweden.

The issue of tyres recycling is of great environmental importance, since rubber is highly resistant to natural impact and therefore tyre pollution is very durable. Meanwhile, recycling scrap tyres is economically beneficial.

Currently scrap tyres are used as:

- Fuel;
- Crumbs and powder utilized as fillers;
- Different products in civil engineering.

Annually about 800 million of scrap tyres are discarded in the world, and this amount is estimated to increase by almost 2% per year.

The main negative impact of scrap tyres on the environment and human health results from leaching hazardous chemicals into the soil, surface and ground waters, which occurs during landfilling or long-term storage of tyres in the open place. Besides, open incineration of scrap tyres results in air emissions of potentially hazardous amount of carbon oxide and different mono- and polyaromatic carbohydrates and other harmful substances.

The main factors facilitating the reduction of tyres landfilling rates are the corresponding legal requirements.

The European Commission Directive 1999/31/EC on the landfill of waste states that scrap tyres, as well as shredded tyres are not to be accepted in a landfill.

Directive 2000/76/EC on the incineration of waste sets maximum permissible emission levels for incineration of scrap tyres in cement kilns.

Implementing an efficient collection and disposal system for transport tyres is a difficult technical, material and environmental task in the whole world.

The main methods of scrap tyres treatment include:

- Reuse of scrap tyres after their restoration and/or vulcanization;
- Recovery of useful materials;
- Recycling with energy recovery;
- Accumulation and landfilling.

The most frequent option for reuse of unrecycled tyres is utilization as shock absorbers in ports and foundations for temporary road signs.

Materials recovery from scrap tyres is rather problematic due to the necessity to separate rubber from the metal cord. The most widespread methods of separation are based on cryogenic processing and shredding with the subsequent magnetic and other types of separation. Powder and crumbles obtained by processing rubber are mainly used in road building, in different surfaces and for footwear manufacturing.

Recycling tyres is rarely economically beneficial; therefore many countries impose compulsory sales taxes to cover for the expenses.

Incinerating scrap tyres is the most acceptable treatment method due to high calorific value of tyres (comparable to that of oil). Incineration can be performed either in special facilities or in cement kilns. Although incineration of tyres releases dioxins, particulates and other environmentally and human- hazardous substances, this treatment method is one of the most frequently used.

Another method of scrap tyres treatment is pyrolysis, which produces oils and noncombustible particles.

Currently tyre treatment methods can differ significantly in different countries, but in the European Union there is a marked tendency towards the methods facilitating energy and materials recovery.

Based on the comparative analysis of the negative environmental impact produced by different treatment methods, the most acceptable method for scrap tyres is incineration with energy recovery.

Analysis shows that restoration and shredding of scrap tyres with subsequent reuse in road building produces less negative impact on the environment than chemical recycling, which in turn, is less harmful than incineration of tyres at power plants. The main positive aspect is that tyres restoration saves virgin raw materials required for the production of new tyres. Besides, account should be taken of the fact, that production of new tyres consumes 15 times more energy than restoration of the old ones.

In general, restoration of tyres saves up to 80% of virgin raw materials and reduces the amount of generated waste.

The cost of restored tyre is 30-50% lower than that of the new one. Restoration allows to increase the life time of protectors and therefore postpones the necessity of their disposal. The output of new tyres and the amount of scrap ones reduces as the restoration rates increase. Nevertheless, restoration is not a solution to the problem in general, since in the end tyres still need to be disposed of. Therefore the search of alternative treatment methods continues.

Chapter 16
Waste to Energy

16.1 Energy from waste

Waste-to-energy (WtE) or energy-from-waste (EfW) is the process of generating energy in the form of electricity and/or heat from the primary treatment of waste. WtE is a form of energy recovery. Most WtE processes produce electricity and/or heat directly through combustion, or produce a combustible fuel commodity, such as methane, methanol, ethanol or synthetic fuels.

Waste to energy is a recovery method that provides a significant part of Europe's energy needs. One example of this is that around 50 million tons of waste are processed through incineration every year throughout Europe. This corresponds to the heat requirements for the populations of Sweden, Norway, Iceland, Finland, Denmark, Estonia, Latvia, and Lithuania. In Sweden alone, waste incineration generates as much energy as 1.1 million cubic meters of oil, which reduces carbon dioxide (CO_2) emissions by 2.2 million tons per year. This is as much CO_2 as 680,000 petrol-powered cars emit a year.

During the 1970s and early 1980s, many of the world nations became gravely affected by the high cost of imported oil and by the scarcity of low-cost alternative fuels. This situation precipitated a search for alternative sources of energy, which in turn led to a renewed interest in urban wastes as one potential source. The renewed interest in the energy potential of urban wastes was not surprising, for two reasons: 1) a sizeable fraction of the waste, depending on the country, can consist of combustible components, i.e., materials that can serve as a fuel in the production of heat energy; and 2) incineration of municipal waste and use of the waste heat produced there from had been practiced in Europe for many years.

Many of the combustible components of municipal solid waste are also biodegradable and, thus, can serve as substrates for biological conversion to a fuel gas that is immediately converted into energy (i.e., direct conversion into heat energy), or that can be stored or transported for later conversion (i.e., indirect conversion). The energy potential of all urban wastes is not the same, in that they differ both in energy content and in the ease with which the energy can be "extracted".

Energy can be extracted from solid wastes in many ways. A schematic diagram of the various methods of energy recovery, and of the types of fuel and forms of energy that can be produced from municipal wastes, is presented in Figure 16.1.

As the scheme illustrates, energy recovery can be accomplished with or without mechanical, manual, or mechanical/manual processing of the wastes prior to their conversion (i.e., pre-processing). Energy recovery without pre-processing is accomplished by conversion of the wastes predominantly in the form in which they were generated. Energy recovery through pre-processing is accomplished by one or more of the methods shown in the figure. The main objective of pre-processing a waste for energy recovery is to segregate the organic or combustible fractions from the remainder of the waste, i.e., the non-combustibles.

16.2 Incineration and refuse-derived fuel production

Incineration is a waste treatment process that involves the combustion of organic substances contained in waste materials. Incineration and other high-temperature waste treatment systems are described as "thermal treatment". Incineration of

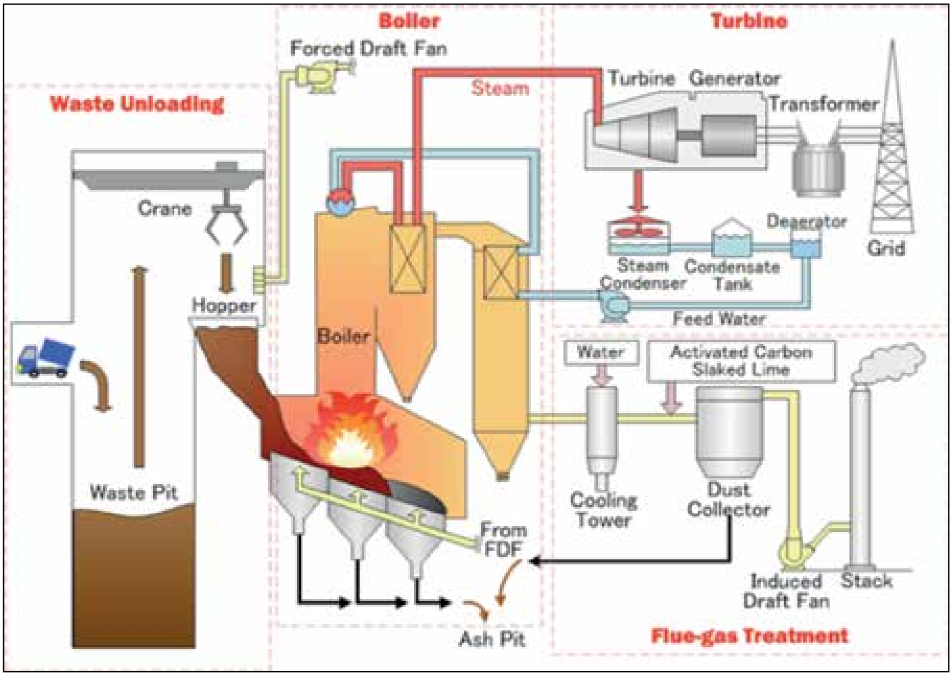

Figure 16.1 The scheme of waste incineration and energy production

Figure 16.2 SYSAV incineration plant in Malmö, Sweden, capable of handling 25 metric tons per hour of household waste.

waste materials converts waste into ash, flue gas, and heat. The ash is mostly formed by the inorganic constituents of the waste, and may take the form of solid lumps or particulates carried by the flue gas. The flue gases must be cleaned of gaseous and particulate pollutants before they are dispersed into the atmosphere. In some cases, the heat generated by incineration can be used to generate electric power.

Incineration with energy recovery is one of several waste-to-energy (WtE) technologies such as gasification, pyrolysis, and anaerobic digestion. While incineration and gasification technologies are similar in principle, the energy product from incineration is high-temperature heat whereas combustible gas is often the main energy product from gasification. Incineration and gasification may also be implemented without energy and materials recovery.

Incinerators reduce the solid mass of the original waste by 80-85% and the volume (already compressed somewhat in garbage trucks) by 95-96%, depending on the composition and degree of recovery of materials such as metals from the ash for recycling. This means that while incineration does not completely replace landfilling, it significantly reduces the necessary volume for disposal. Garbage trucks often reduce the volume of waste in a built-in compressor before delivery to the incinerator. Alternatively, at landfills, the volume of the uncompressed garbage can be reduced by approximately 70% by using a stationary steel compressor, albeit with a significant energy cost. In many countries, simpler waste compaction is a common practice for compaction at landfills.

Incinerators may emit fine particulates, heavy metals; trace dioxin and acid gas, even though these emissions from modern incinerators are relatively low. Other concerns include the proper management of residues such as the toxic fly ash, which must be handled in a hazardous waste disposal installation as well as the incinerator bottom ash (IBA), which must be reused properly.

Critics argue that incinerators destroy valuable resources and they may reduce incentives for recycling. The question, however, is an open one, as countries in Europe recycling the most (up to 70%) also incinerate their residual waste to avoid landfilling.

Incinerators have electric efficiencies of 14-28%. In order to avoid losing the rest of energy, it can be used for e.g. district heating (cogeneration). The total efficiencies of cogeneration incinerators are typically higher than 80% (based on the lower heating value of the waste).

The method of using incineration to convert municipal solid waste (MSW) to energy is a relatively old method of WtE production. Incineration generally entails burning waste (residual MSW, commercial, industrial and refuse-derived fuel – RDF) to boil water which powers steam generators that make electric energy and heat to be used in homes, businesses, institutions, and industries. One problem associated with incinerating MSW to make electrical energy is the potential for pollutants to enter the atmosphere with the flue gases from the boiler. These pollutants can be acidic and in the 1980s were reported to cause environmental damage by turning rain into acid rain. Since then, the industry has removed this problem by the use of lime scrubbers and electro-static precipitators on smokestacks. By passing the smoke through the basic lime scrubbers, any acids that might be in the smoke are neutralized which prevents the acid from reaching the atmosphere and hurting the environment. Many other devices such as fabric filters, reactors and catalysts destroy or capture other regulated pollutants. According to the German Environmental Ministry, "because of stringent regulations, waste incineration plants are no longer significant in terms of emissions of dioxins, dust, and heavy metals".

The value of wastes in direct conversion lies primarily in their energy content or heating value. Chemical elements that make the greatest contribution to the heating value of wastes are principally carbon and hydrogen. On the other hand, the fuel value of the wastes is adversely affected by moisture content and the inclusion of non-combustible materials.

Figure 16.3 Powerful and effective electrostatic filters have been installed at the incineration plant SYSAV, Malmo to clean and catch harmful emitted gases.

The fuel value of the refuse-derived fuel, as well as the actual incineration of the material, is decided in large part by the composition of the wastes. For example, the relatively high moisture content of putrescible materials must be lowered before ignition can take place. The energy to accomplish this removal must come from that released when dry materials are burned, or by supplying additional energy by combusting supplemental (e.g., fossil) fuels along with the wastes.

The urban wastes generated in several countries in transition can be approximately 50% to 70% putrescible on a wet weight basis. On the other hand, the quantities of discarded paper and plastics are relatively small. Therefore, the overall percentage of dry, combustible (volatile) matter is small. Additionally, the ash content of urban wastes in some locations in developing countries can be substantial (e.g., up to 60% where wood ash, coal ash, or both are major waste byproducts of domestic activities). The combination of these attributes of the wastes can render the waste conversion system as a net user of energy, as opposed to a net supplier. The upshot of this situation is that incineration and thermal processing for energy production may not be applicable to such countries, or may be feasible only in certain locations or under special conditions.

The incineration of raw (unprocessed) wastes is practiced throughout the world, particularly in European countries where it has been in use for decades. The simplest and crudest method of incineration is open burning. With the successive changes that have taken place in technology in general and in environmental

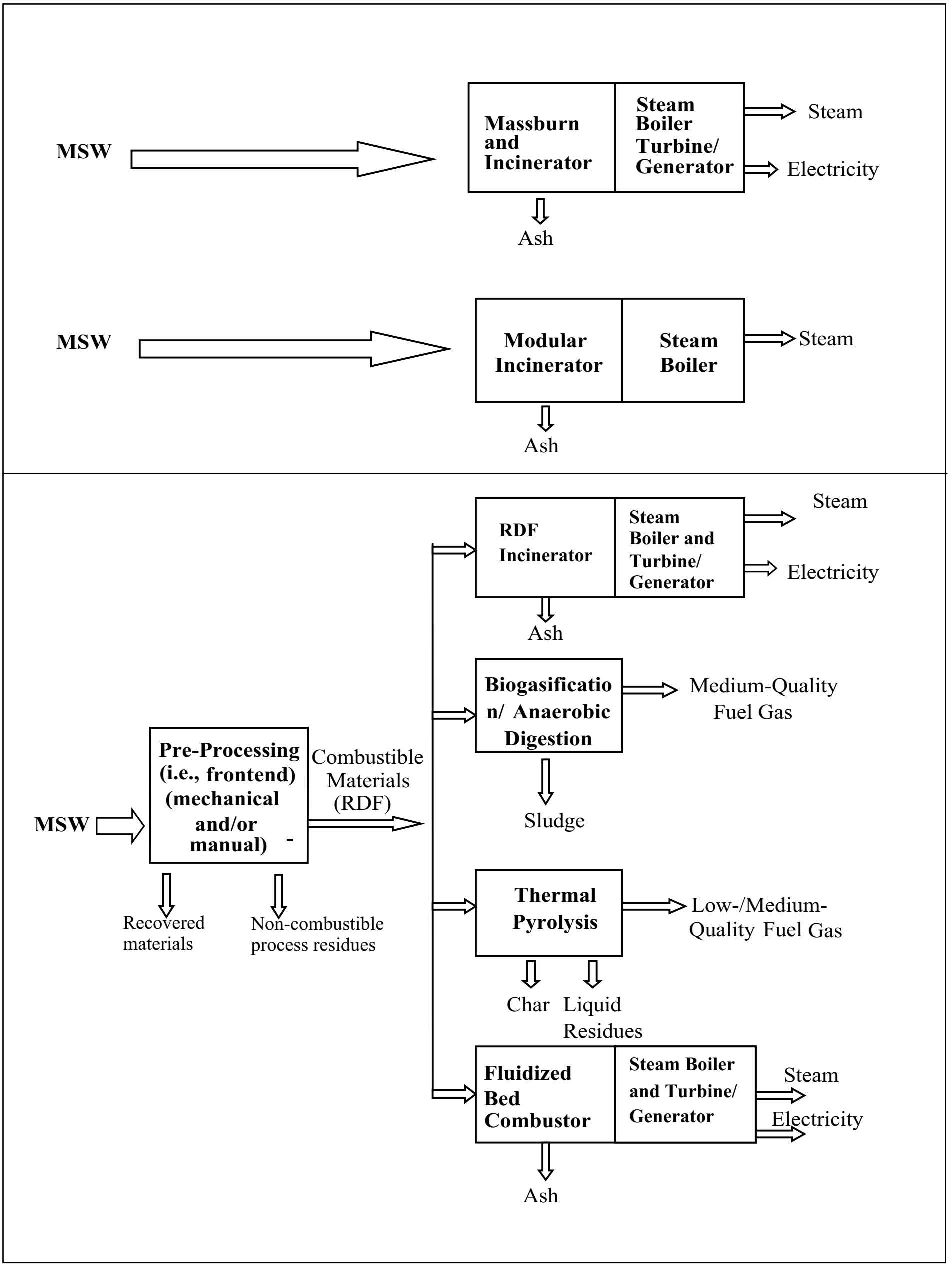

Figure 16.4 Examples of methods of recovering energy from solid waste

concerns, the combustion process gradually has become subjected to increasingly "controlled" conditions. Initially, the main objective of the process was to reduce the volume of the material requiring disposal. Later, the products of combustion (hot gases) were used to generate steam.

Incineration of raw wastes has its advantages and its disadvantages. Two main advantages come to mind, particularly for an energy- and space-hungry, densely populated metropolis; they are the potential for generating steam and the accomplishment of volume reduction. On the other hand, incineration has a serious disadvantage in the form of the substantial cost of controlling and managing its pollutant emissions. The general forms of the pollutants generated during the course of incineration include air emissions, bottom and fly ash, and wastewater. Another important disadvantage is the fact that the direct combustion of the raw wastes does not provide an opportunity for substantial recovery of material resources.

16.3 Thermal gasification and biogasification

"Gasification", as used in solid waste management, is a term applied to the conversion of wastes into a gaseous fuel. The term is used even though not all of the recovered energy is in the form of a combustible gas. Indeed, with certain processes, the fraction in the form of a combustible gas may be much less than that in a solid or a liquid form, or in both. Because gasification can be a complex and expensive undertaking, recourse to it for energy recovery should be considered only in certain special circumstances. For example, there might be a local need for an organic gas as a chemical feedstock or a gaseous fuel to supply a gas-fired industrial process. Such circumstances preclude the presence of an economical supply of fossil ("natural") gas.

Gasification may be accomplished by biological and non-biological processes. Biological gasification involves the collective activities of groups of facultative and obligate anaerobes in the conversion of 30% to 40% of the energy bound in the biodegradable fraction of wastes into the chemical energy of methane. The process by which the transformation is accomplished is a well-known one, and usually is referred to as "anaerobic digestion", although the terms "methane fermentation" and "biogasification" may be used synonymously. Generally, "biogasification", as used in the literature, has a rather generic connotation, whereas "anaerobic digestion" is regarded as implying the usage of specialized equipment (reactors) and the adherence to a well-defined operational procedure. Inasmuch as biogasification takes place in nature where and whenever conditions are appropriate, it is not surprising that it takes place in a landfill. This latter phenomenon, while widely known for many years, has only recently been put into extensive beneficial use, i.e., landfill gas recovery and utilization.

Non-biological gasification processes are thermal (or thermal-chemical) in nature. Through them, both non-biodegradable and biodegradable combustible matter can be transformed. Because of this attribute, the percentage of energy recovery from non-biological gasification processes potentially can surpass that from biological systems. Non-biological gasification, or as it is more commonly termed, "pyrolysis", essentially is the fractional distillation of the organic matter in a waste under O_2-free, or partially O_2-free, conditions. The end products are gases, liquids (oils and tars), and solids (char). The extent of the gasification in terms of percentage of the end products in the gaseous form is primarily a function of elevation of temperature and, to some degree, of pressure. If a high yield of combustible gas is the objective of the process, then steps must be taken to elevate the temperature at some point in the process since the temperature of "strict" pyrolysis reactions results in low gas yields. One such step is to combust a portion of the gas stream by admitting a small amount of O_2 into the process, such that the overall process is a two- step one - strict pyrolysis followed by limited combustion. This has led to the development of the "pyrolysis-combustion" type of process. Occasionally, the term "gasification", or more specifically "thermal gasification", is restricted to pyrolysis-combustion, while "pyrolysis" is used solely for pyrolysis in the strict sense of the term.

The possibility of biologically recovering energy in the form of the combustible gas, methane, has prompted an interest in applying *biogasification* to waste treatment in many countries alike. The attraction to the concept arises from the fact that biogasification of solid waste serves a dual function of waste treatment and energy production. If viewed solely as a solid waste treatment method, biogasification probably does not rank with composting in terms of technical and economic practicality and feasibility in most economically developing countries. Biogasification plant design and operation are more expensive and allow much less latitude of scale and level of technology than composting. Equipment needs are more rigorous, and maintenance and processing demand a higher level of personnel competence. However, biogasification is more practical than composting for treating readily degradable wastes (such as some food wastes), nightsoil, and body wastes. Moreover, it can be very practical when used in conjunction with sanitary landfilling.

Biogasification is defined as being the biological decomposition of organic matter of biological origin under anaerobic conditions with an accompanying pro-

Figure 16.5 The scheme of a biogas complex in the agricultural complex "Snou", Belarus, electric capacity is 2,1 MWt.

duction primarily of methane (CH_2) and secondarily of other gases, the main one of which is carbon dioxide (CO_2). The two features that distinguish the process as defined from other forms of biological decomposition are "under anaerobic conditions" and "the production of methane".

A feature that has a major influence on the application of biogasification in waste treatment is the fact that, conventionally, the process takes place in more or less distinct stages or phases. The stages are distinct in that they can be separated from each other with respect to reactions, reaction products, and microflora. Generally, it is held that the number of stages is two - acid stage followed by a methane forming stage. However, some researchers hold that three stages are involved when the substrate is a waste. In that view, the two conventional steps are preceded by a "polymer breakdown" step when a waste is the substrate.

The process is sequential in that the acid stage precedes the methane forming stage regardless of whether the culture (i.e., digester) is operated on a batch or a continuous basis. In a continuous type of operation, all stages may be encountered at any time. This is true because all input must pass through the sequence. Therefore, if the operation is on a continuous basis, all stages would be represented at any point in time, and newly introduced material would be going through the acid stage; whereas, simultaneously, material previously introduced may already be in the methane-forming stage.

The end products of the final stage are methane, carbon dioxide, trace gases, and a satisfactorily stable residue.

Generally, biogasification proceeds more rapidly with a mixed collection of hydrolytic microbes than with a single (pure) culture. The faster pace is partly due to the synergistic action resulting from the interaction of several types of microbes.

A likely outcome of the synergism is the destruction of potentially inhibitory byproducts.

A restrictive factor is the pH level. Whereas for the acid stage, the tolerated pH range is as wide as pH 4.5 or 5.0, to 7.5 or even 8.0, the permissible range for the methane stage is only pH 6.0 to 7.5. The optimum level is pH 7.0. Key environmental factors (i.e., those that relate to culture and growth conditions) include oxidation reduction level, hydrogen ion concentration (pH), temperature, and substrate.

A direct relation exists between the extent and intensity of a microbial activity and temperature level within a temperature range tolerated by the organisms. Each range characteristically has a minimum level below which no activity occurs and a maximum level above which all activity ceases and the microbes do not survive. Within the survival range, activity and growth increase with rise in temperature until an optimum level is reached, and decrease after the optimum level is reached. In the biogasification process, this influence is manifested by changes in the rate and volume of gas production, and the rate and amount of volatile solids destroyed.

In practice, temperature ranges have been grouped into two broad classes or types - mesophilic and thermophilic. Correspondingly, the microorganisms that have mesophilic ranges are termed mesophiles; those having a thermophilic range are termed thermophiles. The mesophilic range begins at about 10° to 15°C, peaks or plateaus at about 35° to 38°C, and ends at about 45°C. The thermophilic range begins at 45° to 50°C, peaks at 50° to 55°C, and ends at 70° to 75°C.

Some types of microorganisms can survive and perhaps thrive under both temperature regimens. Mesophilic microorganisms that can tolerate thermophilic conditions are termed facultative thermophiles; equally, tolerant thermophiles are termed facultative mesophiles. Microorganisms lacking such tolerance are designated obligate mesophiles or thermophiles, as the case may be. A mesophilic culture can be adapted to thermophilic conditions. However, as will be explained later, there is a considerable reason for attributing the so-called adaptation to the enrichment. Consequently, to operate a digester under thermophilic conditions, either an existing culture of

thermophiles must be used, or one must be developed. Development, whether it is adaptation or enrichment, is a slow process. Most likely, successful development will be the result of a chance occurrence of a “wild” strain of thermophiles in the “starting culture”.

As is true with most biotreatment systems, the waste to be treated serves as the substrate and feedstock for the microbial populations that are active in the

Table 16.1 Biogas production from digestion of common wastes Source: Diaz, L.F.,at.al.(1981)

Raw Material	Biogas/Unit Wt of dry solids (m^3/kg)	Temperature (°C)	Methane content of gas (%)	Detention time (days)
Cattle manure	0.20 to 0.33	11.1 to 31.1	--	--
Poultry manure	0.46 to 0.56	32.6 to 50.6	58 to 60	9 to 30
Swine manure	0.49 to 0.76	32.6 to 32.9	58 to 61	10 to 15
Sheep manure	0.37 to 0.61	--	64	20
Forage leaves	0.5	--	--	29
Sugarbeet leaves	0.5	--	--	11 to 20
Algae	0.32	45 to 50	55	11 to 20
Nightsoil	0.38	20 to 26	--	21
Municipal refuse	0.31 to 0.35	35 to 40	55 to 60	15 to 30

biological phases of the treatment. The suitability of a waste as a substrate depends upon three characteristics including physical properties, chemical composition, and biodegradability. Actually, biodegradability is determined in large part by the physical properties and chemical composition of a waste. With respect to chemical composition, possession of nutrient (fertilizer) elements and molecular structure of the compounds that contain them are the pertinent characteristics.

An advantageous feature of physical properties in general is relative ease of changing or adjusting them to improve their utility as a feedstock. Two such properties are particle size and moisture content.

With regard to chemical composition of substrate and feed, elemental composition and the structure of the molecules that contain essential elements are main considerations. Essential nutrient and metabolic elements are conventionally arranged into two groups -- namely, “macronutrients” and “micronutrients”. However, this arrangement neglects essential elements that do not fit within these two groups; among them are calcium and magnesium. The micronutrients (“trace elements”) include sodium, cobalt, manganese, and a number of other metallic elements. Most wastes contain the full array of essential trace elements.

Because of a tendency to float, wood, straw, rice hulls, and other wastes of low density do not constitute suitable materials for low-solids digestion systems. The unsuitability is due to the propensity of low-density wastes to intensify scum formation. Consequently, it becomes necessary to control the more or less thick surface layer of scum that characterizes conventional anaerobic digestion.

Gas production ranks highest among the parameters commonly used to judge cultural performance and guide digester operation. It is a direct measure of

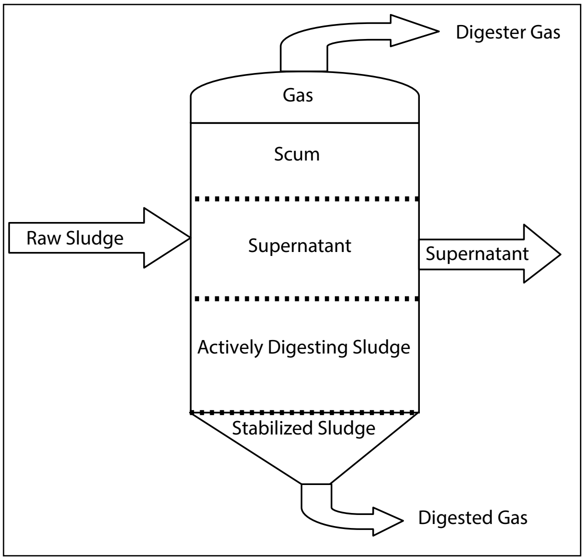

Figure 16.6 Conventional digestion (low solids)

overall microbial activity. In combination with the parameter, composition, it is a measure of the activities of the methanogens. The combination of the two parameters is a measure of energy recovery efficiency and economic practicality.

Gas volume per unit of volatile matter depends both upon the detention period and other operational features, and upon the nature of the waste. Gas production can be amounted to 0.374 to 0.454 m^3/kg of raw sewage solids introduced.

The use of gas production as a parameter depends not only upon the volume of gas produced, but also upon its composition. In waste treatment, the components of interest are carbon dioxide and methane. Methane is the more useful of the two and, hence, significant. Two factors determine the magnitude of the methane content - substrate and the methanogen population, i.e., the density and intensity of activity of the latter. With regard to the substrate, a predominance of carbohydrates usually results in a 1:1 ratio of methane to carbon dioxide. Accordingly, 50% of the gas produced is methane. Conversely, the use of a highly nitrogenous substrate (e.g., raw sewage sludge) may result in a gaseous product that is 65% methane.

The composition and quality of raw (untreated) biogas directly after its emission from a digester or a landfill vary widely from day to day. The result is a wide range of values for each component. As stated in the section on parameters, the two principal components of biogas are methane (CH_2) and carbon dioxide (CO_2). From 55% to 65% of the biogas is methane; and 34% to 44% is carbon dioxide. Lesser gases include H_2S, N_2, and H_2O. The heating value of raw biogas ranges from 18,630 to 26,080 kJ/m^3. The raw gas can be burnt and the resulting heat can be used in any one of several uses. Although the raw gas can be used as a fuel in internal combustion engines, its hydrogen sulphide content would cause considerable corrosion in the engine.

Most of the potential uses of biogas demand that the quality of the gas be uniformly high and the composition vary minimally. Unfortunately, the moisture content of raw biogas may range from as low as 5% to saturation. Variations in moisture and hydrogen sulphide content can be as much as 50% from day to day and season to season. An intrusion of atmospheric oxygen in the gas could have serious repercussions in terms of explosion potential.

16.4 Landfill gas recovery and utilization

Landfill gas (commonly termed "biogas" in some locations) is one of the products generated as a consequence of the biological degradation of the organic fraction of the wastes placed in the landfill. Immediately after disposal and for a brief period afterwards, there is enough oxygen contained in the air entrapped in the wastes so that the initial phase of biodegradation is primarily aerobic. The main constituents of the landfill gas during this stage are carbon dioxide (CO_2) and water vapor.

Waste compaction, combined with the application of the landfill cover, prevents air from reaching the wastes. Consequently, within a short period of time from initial deposition, the oxygen originally trapped in the wastes is consumed and the biodegradation process becomes anaerobic. The shift to anaerobiosis is marked by the production of methane (CH_4) and carbon dioxide (CO_2), as well as a variety of trace amounts of reduced carbon and sulphur compounds.

Typically, the composition of landfill gas is on the order of 40% to 60% CH_4, 40% to 50% CO_2, 3% to 20% N_2, 1% O_2, and traces of sulphides and volatilised organic acids. Traces of other compounds may include benzene, toluene, sulphur dioxide, methylene chloride, and others in concentrations of up to 50 ppm.

Methane is not formed immediately after the waste is deposited in a final disposal site. In some cases, it may take months or even years before the necessary microbial populations are established and the proper environmental conditions within the fill are reached.

Although most municipal wastes in developing countries have a high concentration of organic matter, the wastes usually are not adequately covered and thus the gases readily escape. In addition, there are several factors that affect the amount and rate of gas production in a solid waste disposal site. Some of these factors include:

- Waste composition (i.e., concentration of carbon, nutrients, and inhibitors) and moisture content;
- Degree of pre-treatment (size reduction, recycling, composting, baling);
- Type and degree of compaction, method of operation of the landfill site, type and thickness of cover material;
- Quantity of refuse, geometry, and hydrogeologic properties of the landfill; and
- Climatic conditions (temperature, precipitation, evaporation, insulation).

The concentration of carbon in municipal solid waste can vary from 325 to 350 kg/Mg (dry basis). The amount of degradable carbon is in the range of 56% to 70%. The theoretical maximum production of landfill gas is about 300 m^3/Mg of MSW (wet basis).

Gases generated in the fill can either be allowed to disperse and migrate beyond the confines of the fill without any effort being made to control them, or they can be collected. Collected gases may be put to some use, may be flared, or may simply be vented into the environment. Venting into the environment provides undesirable contributions to global warming. However, the collection and use of landfill gas entails significant capital and operating costs that must be compared to alternative sources of energy.

Accumulated gases and uncontrolled dispersal and migration can lead to the development of undesirable or hazardous conditions due to flammability, asphyxiating properties, and trace organic composition of the gases. The slightly positive pressure usually existing within a landfill permits gases to flow uncontrolled from the fill to areas of lower gas pressure by convective gas transport. In addition, if cover is applied in an unmanaged fashion, the gas accumulated in the fill is likely to be inhibitory to the growth of roots of any vegetation that is placed on the cover.

In the absence of adequate gas control, landfill gases either migrate to the atmosphere through the landfill cover or migrate laterally through the soil around the fill until they reach areas from which they cannot escape and, as a result, accumulate. As long as the concentrations are relatively low, the gases pose only a nuisance; but when the concentration reaches a critical point, explosive levels of methane may be reached. (The explosive concentration level of methane is between 5% and 15% by volume. At higher concentrations, methane simply burns.) Because of the possibility of gas accumulation, buildings on or near landfills should not have underground structures. If such structures are present, they should be thoroughly and continuously ventilated and monitored for presence of methane.

Figure 16.7 The landfill MERAB near the Swedish town of Ronneholm produces energy for its own needs from the collected landfill gas; this energy is also used for the common network. The roof of a small-scale generator installation is equipped with the burner for the post-combustion of flue gases.

Accumulation of gases in the fill can be avoided through the use of a porous final cover. Migration from the fill and the attendant hazards can be averted by providing an area of high permeability vented to the atmosphere. Gases flow to the surface of the vented areas where they are diluted in the atmosphere to harmless levels. The areas take the form of boreholes, of gas wells, or of interceptor trenches installed around the borders of the fill. A more useful measure is to recover (collect) the gas and use it as a source of energy.

Gas recovery involves designing the fill such that the migrating gas can be controlled and collected. Collected gas either can be used directly as a low-heat fuel, or can be processed (purified) to form a high-heat fuel. Collection is made possible by providing a combination of strategically spaced wells and areas of high permeability through which gases are channeled to collection points. This is done by installing underground venting pipes and a gravel layer between the cover and the waste, or gravel filled trenches. The gas is removed from the landfill by way of a piping or header system to transport the gas, and blowers to pull the gas from the fill through the headers.

Unless the gas is to be used for simple space heating and household cooking, it should be upgraded before being put to use. Upgrading is essential if the gas is to be used as a fuel for an internal combustion engine, or is to be injected into existing transmission lines.

Quality and content of landfill gas do not compare favorably with those of natural gas. Moreover, its composition and other characteristics are more variable. With regard to the latter, the heat and moisture contents and oxygen concentration of landfill gas may vary as much as 50% from day to day and season to season. The heat content of landfill gases ranges from about 7,500 to 22,000 kJ/m^3; whereas the lowest heat content of natural gas is approximately 37,300 kJ/m^3. Moisture content may be as low as 5% and as high as saturation. Oxygen content varies from trace levels to levels that are potentially explosive. However, the latter levels are reached very infrequently. Finally, the usually sizeable CO_2 and N_2 contents of landfill gas materially lower its heat content and, hence, the quality of the gas.

The utility of landfill gas can be increased significantly by upgrading the gas. Among the uses for upgraded gas are onsite generation of electricity and/or injection into a public utility transmission line. Methods and procedures are available for removing H_2O (dehydration), CO_2, and N_2 from landfill gas, and thereby considerably raising its heating value.

Chapter 17
Dealing with Industrial Waste

17.1 Construction and demolition waste

Construction and demolition waste (CDW) is one of the heaviest and most voluminous waste streams. It accounts for approximately 25% - 30% of all waste generated in the EU. Construction and demolition debris are generated regularly in urban areas as a result of new construction, demolition of old structures and roadways, and regular maintenance of buildings. These wastes contain concrete, cement, bricks, asphalt, wood, metals, and other construction materials that are typically inert. In many cases, the biological inertness of construction and demolition debris means that it can be disposed in landfills with lesser restrictions than those required for MSW, which has substantially higher biodegradable content and potential for polluting the environment. However, it must be pointed out that such debris may contain some hazardous materials, such as asbestos and PCBs, although this circumstance is most probable in the case of industrialized countries. Very large volumes of demolition waste are generated during natural disasters (earthquakes, floods, typhoons, and others) and during wars.

City authorities need to protect against disposal of these wastes in the streets and on vacant lands, since these locations can become illegal, uncontrolled dumps with their attendant negative consequences. On the other hand, disposal of this debris in MSW landfills can be costly and is a poor use of landfill capacity. Thus, other alternatives to dispose of the construction and demolition waste may be warranted and should be considered in any event.

It is well known, the management and disposal of CDW are beset with numerous problems, most of which relate to handling, storage, transportation, and disposition either by recycling or by final disposal. These problems are largely due to the nature of the wastes. A characteristic that frequently magnifies the problems is bulkiness. The bulk density of CDW is a function of that of its components.

Bulkiness and heaviness, along with resistance to compaction, seriously constrain the landfill option. High cost rules out particle size reduction (shredding, grinding) merely as a means of compensating for bulkiness. However, it is justified if it were a unit process in recycling. Disposal by incineration is impractical since the material is mostly inert.

A seemingly obvious solution to disposal difficulties is to avoid them through recycling. Although CDW may be difficult to handle and to move, it potentially is rich in terms of inorganics that compare favorably with those of virgin materials. However, wood may be an exception.

Concrete debris comes from the razing of buildings and the demolition of other structures, roads, and highways, and may represent 10% to 40% of CDW. In the past several decades and continuing today, a significant fraction of the concrete debris was and is recycled after only a minimum of processing that consists of reducing the concrete chunks to a size required by their intended use. The uses are many and varied. For example, they may be used in dike construction, or may provide an "all-weather" temporary roadbed in a waste disposal site.

The physical characteristics of CDW are such as to need the use of relatively expensive equipment for processing it into its marketable components. A promising means of lowering the resulting unit cost of processing is to rely upon portable equipment that can be moved from one demolition operation to another. Equipment cost has not deterred some contractors from designing and operating CDW processing facilities. The facilities usually incorporate some or all of the following operations to produce marketable materials: screening, size reduction, magnetic separation, density separation, and manual sorting.

Figure 17.1 Processing of construction waste (reinforsedconcrete) at the crushing plant. The processed material (rubble) will be used for road construction.

Table 17.1 Construction waste generated after the dismantling of buildings

Material	Sources
Wood	Wood bearing structures, sawn timber, plywood, laminated coating, chips
Lime	Gypsum, plaster
Metals	Pipes, rebar, waterproof key, aluminum, copper, brass, stainless steel
Plastic	Vinyl siding, doors, windows, floor tile, pipes
Roofing	Tar board shingles, shingles, slate, roofing felt
Cobblestone	Asphalt, concrete, foundation, soil, clinker blocks
Brick	Bricks and decorative tile
Glass	Windows, mirrors, lights
Other materials	Carpeting, fittings, insulation materials, ceramic tile

"Sorting" exemplifies the "dual nature" of concrete debris processing. Sorting is twofold: the separation of concrete debris from other CDW, and the classification of the separated concrete debris. Separation from other debris usually is one of the demolition activities and, thereby, begins at the demolition site. At this point, segregation may be performed manually, mechanically, or both. The role of sorting in this stage is to retrieve recyclable materials. It is exemplified in the demolition of a building that has one or all of the following: concrete walls, floors (slabs), and columns. Steel and/or wire present in the structures is removed manually as the demolition progresses.

The other aspect of sorting is the separation and classification done in the processing sequence. This sorting usually is mechanized and largely consists of screening. The screening may be preceded by size reduction and be augmented by magnetic removal of ferrous material, and flotation to separate wood and plastics. These processing operations may be performed onsite, with the use of portable equipment, or at a central facility.

Size reduction is one of the more important processing steps. It usually is carried out by a specially designed crushing machine ("shredder") or by a grinder. Obviously, the machines must be rugged. Discharge from the machines is screened and further processed. As stated earlier, the discharge may serve as an aggregate for use in roadbed construction or may be further processed (refined) to the extent required for a particular use. A likely use would be for making concrete. A careful analysis of the concrete must be performed to ensure that it meets national standards.

Construction is a much more common source of less hazardous waste then dismantling works. Dismantling leads to the forming of waste of materials subjected to chemical treatment and containing different chemical elements, heavy metals or asbestos that can cause soil contamination during burial or improper

Table 17.2 Hazardous materials and substances in the composition of construction waste (KEMI, 1999).

Chemicals	Sources	Impact
Phthalates (used aa an absorber)	PCBs in floor covering, condensers and cables	Cause disruptions of the endocrine system
Polyurethane	Binder in the composition filler	Presumably carcinogen
Cadmium	Stabilizer in plastics and dyes	Accumulative. Harmful to bones and liver. Affects the hematopoietic system.
Solvents	Solvents, adhesives	Carcinogens
Lead	Electrical and telephone cables, sheet steel, pipes	Nervous system disorders
Mercury	Fluorescent lamps, electrical switches or thermostats	Accumulative. Affects the central nervous system. Dangerous for the reproductive system. Allergen.
Chloroparaffins	Floor covering, cables, paint, glue, filler	Carcinogen

handling. In its turn, precipitation leads to the leaching of these substances and causes the pollution of groundwater.

Table 17.2 describes several types of hazardous construction waste as well as their impact on man's health and environment.

To reduce the flow of hazardous waste to be buried it is extremely important to pre-sort; after that harmful chemicals should go to the treatment and neutralizing enterprises. However, the level of recycling and re-use of CDW waste varies greatly (between less than 10% and over 90%) across the European Union. In some member states, this waste stream is to a large extent disposed of, using up valuable space in landfills.

In addition, if not separated at source, it can contain small amounts of hazardous wastes, the mixture of which can pose particular risks to the environment and can hamper recycling.

One of the objectives of the European Waste Framework Directive is to provide a framework for moving towards a European recycling society with a high level of resource efficiency. In particular, Directive stipulates that "Member states shall take the necessary measures designed to achieve that by 2020 a minimum of 70% (by weight) of non-hazardous construction and demolition waste shall be prepared for re-use, recycled or undergo other material recovery (including backfilling operations using waste to substitute other materials).

Sound practices for the management of construction and demolition wastes are based on the concept of prevention, reuse, and recycling of waste. When these practices cannot be implemented, proper disposal must be considered. Since these wastes are primarily inert or they can be processed to be so in some cases, they can be used for fill, for example in former quarries, as road base, or in coastal cities. Special construction and demolition landfill sites are also an option. Siting of these landfills is less difficult than for regular MSW landfills since the potential environmental impact is relatively small.

Some sound practices for diverting construction and demolition debris from landfill disposal are described in Box 17.1.

17.2 Disposal of sludge from various industries

The so called *sludge* formed during various technological process is a colloid system comprised of fine insoluble particles present in suspension in various liquids. Their number varies greatly depending on the type of production. For instance, the amount of oil sludge generated in *oil refineries* does not exceed 1% of the amount of processed oil while the amount of sludge generated during the *production of phosphorous* reaches 30% of phosphorous production volume.

A significant amount of sludge containing valuable metals and minerals is produced in the chemical industry, mechanical engineering, etc. In many cases, sludge is discharged into the tailings storage facilities and ponds, polluting both the air and underground and surface waters.

Box 17.1. Sound practices for diverting construction and demolition debris from landfill disposal

Waste prevention can be promoted through inventory control and return allowances for construction material. This ensures that unused materials will not get disposed of unnecessarily;

- Selective demolition. This practice involves dismantling, often for recovery, of selected parts of buildings and roadways before the main demolition (wrecking) process is initiated;
- Onsite separation systems, using multiple smaller containers at a construction or demolition site to store sorted recyclable materials, as opposed to gross disposal of mixed materials in using a single roll-off or compactor;
- Crushing, milling, grinding, and reuse of secondary stone, asphalt, and concrete materials. These materials can be processed to conform to a number of standards for construction materials. Recovery and reuse of these types of materials is facilitated by the existence of approved specifications for road construction materials and by governmental procurement policies that promote or stimulate purchase of recyclable materials.

As a rule, sludge is highly toxic and contaminated with organic and mineral impurities. Besides the damage to the environment, a large amount of valuable raw material is lost during its disposal in tailings ponds. The re-use of materials extracted from sludge, on the contrary, allows saving a significant amount of natural resources and reducing the burden on the environment.

Depending on the composition and physical and chemical qualities of sludge different methods of sludge disposal and treatment are used including chemical, physical and chemical, thermal ones and their combinations. In many cases the most common method of sludge disposal is thermal. The firing process allows to completely neutralize combustible components of sludge to produce harmless products of combustion and ash residues consisting of metals and their oxides. Along with the direct combustion thermal methods are often an integral part of the complex technologies of sludge neutralization and disposal.

In these technologies the thermal treatment either precedes or follows the physical and chemical or chemical process of separation of valuable materials from sludge. Such complex methods allow recovering iron from sludge, to restore catalysts containing nickel, palladium, platinum, copper, tellurium and other valuable metals; these metals are also recovered from used catalysts.

Oil waste and oil products are among the main environmental pollutants. They are formed during the transportation of crude oil and its refined products, accidents, cleaning of transportation containers, and in some other cases.

Main consumers of oil products are concentrated in large industrial centers. They are transport enterprises and different industries using fuel, lubricants, cleaning fluids and other petroleum products.

Even though the share of sludge produced in the process of oil processing is small (1%), its total amount at refineries is quite large. As oil sludge contains 20-25% of oil products its disposal is of considerable interest.

Collected in different traps, sumps and slurry tanks oil products go through heated heat exchangers to evaporate water and then go for the upholding. Depending on the quality of the received product it is either burnt or, in case of a high oil content and purity of the received oil emulsion it is sent for refining with crude oil.

More rational methods of oil sludge disposal mean:

- the use of waste heat boilers using heat released during the combustion of dewatered sludge;
- the use of centrifuges for sludge dewatering;
- the use of pyrolysis to receive combustible gases from oil in sludge, the thermal processing of oil waste at a moving solid heat exchanger heated to the

temperature of 350-750°C (oil and water evaporate, then the cooled gas-vapor mixture is condensed and then it settles separating into water and oil products).

The chemical neutralization of oil waste is two times cheaper than incineration. It allows to exclude harm to the environment and to receive products that can be used in road construction and for other purposes. One of the common ways of oil waste disposal is treating it with lime, pretreated stearin acid or another surface active substance. The result is a dry strongly hydrophobic powder that can be used as a construction material for road construction and other purposes.

The biochemical processing of oil waste is based on the ability of certain microorganisms to convert aromatic and aliphatic hydrocarbons into harmless carbon dioxide and water. Conversion of hydrocarbons takes place in aerobic conditions.

A large amount of sludge containing elements that can be used rationally in various technological processes after regeneration is produced during the upholding of wastewater in the galvanic production process. It allows using natural resources rationally and reducing the impact of sludge on the environment.

Depending on the precipitator, sludge generated in the galvanic production process can be divided into:

- containing calcium (precipitator – lime milk);
- containing nitrogen (precipitator – alkali, soda);
- containing iron (precipitator – reagents containing iron).

Dewatering precedes any method of electroplating sludge disposal. The most promising reagentless way of sludge dewatering is, for example, electrocoagu-

Figure 17.2 Applying protective or decorative coatings using the electro-chemical method produces hazardous compounds based as a rule on heavy metals causing serious environmental problems and great difficulties during the precipitation disposal.

lation. The advantages of these methods in comparison with technologies using chemical substances for fine sludge precipitation include the reduction in the duration of the process and of the production areas, in the continuity of the process and improvement of the quality of treated water.

Dewatered galvanic sludge is widely used in the construction material industry. The method of chemical fixation of toxic compounds in sludge is used to eliminate the environmental hazard of galvanic production waste. Fixation is reached through ferritization, silicification, and solidification using binding materials and the sintering of the solid phase.

For instance, chromium-containing sludge after drying is used in the production of decorative glass as a colorant. Depending on the composition of the sludge glass can be obtained in the following colors: green, blue, brown, black and their shades.

Iron-containing sludge after drying is used to produce expanded clay and high quality ferrites.

Hydrometallurgical methods of galvanic sludge treatment are very promising as they allow to selectively extract almost all non-ferrous metals. The humidity of sludge used in these processes should not exceed 10% while the mass of individual pieces cannot exceed 1 kg. When developing such technologies it is crucial to keep in mind that slurries of different metals are incompatible with each other, since zinc is incompatible with nickel, lead with zinc, etc.

Sewage sludge originates from the process of treatment of wastewater. Due to the physical-chemical processes involved in the treatment, the sludge tends to concentrate heavy metals and poorly biodegradable trace organic compounds as well as potentially pathogenic organisms (viruses, bacteria etc) present in wastewaters. Sludge is, however, rich in nutrients such as nitrogen and phosphorous

Figure 17.3 Sewage sludge processing and its application to soil in agricultural sector.

Box 17.2 Sound practices for reducing and handling sewage sludge and septage

- Preventing large volumes of sludge, through separation of sewers and storm drainage systems;
- Minimization of reliance on centralized sewage systems, through the installation of on-site treatment of human waste and household washwater;
- Land application, *but only when very frequent sludge testing shows that metal content is very low, and when the administering authority has the resources and commitment to maintain high standards for such testing*. In practice, this will mean that in many situations the safety of land application is questionable.
- Treatment such as drying, liming, composting, or co-composting with yard waste or organics, followed by land application, which is designed to return the organic matter in sludge to the land. As above, however, contaminants in sludge can make this practice inadvisable for farmland.
- Drying it and disposing of it in landfills. It is important to note that sludge should be dried before entering a landfill in order to avoid generating large volumes of leachate.

and contains valuable organic matter that is useful when soils are depleted or subject to erosion. The organic matter and nutrients are the two main elements that make the spreading of this kind of waste on land as a fertilizer or an organic soil improver suitable.

European Directive 86/278/EEC on Sewage Sludge seeks to encourage the use of sewage sludge in agriculture and to regulate its use in such a way as to prevent harmful effects on soil, vegetation, animals and man. To this end, it prohibits the use of untreated sludge on agricultural land unless it is injected or incorporated into the soil. Treated sludge is defined as having undergone "biological, chemical or heat treatment, long-term storage or any other appropriate process so as significantly to reduce its fermentability and the health hazards resulting from its use". To provide protection against potential health risks from residual pathogens, sludge must not be applied to soil in which fruit and vegetable crops are growing or grown, or less than ten months before fruit and vegetable crops are to be harvested. Grazing animals must not be allowed access to grassland or forage land less than three weeks after the application of sludge.

The Directive also requires that sludge should be used in such a way that account is taken of the nutrient requirements of plants and that the quality of the soil and of the surface and groundwater is not impaired.

The Directive specifies rules for the sampling and analysis of the sludge and soils. It sets out requirements for the keeping of detailed records of the quantities of the sludge produced, the quantities used in agriculture, the composition and properties of the sludge, the type of treatment and the sites where the sludge is used.

Although at the EU level the reuse of sludge accounts for about 40% of the overall sludge production, landfilling as well as incineration in some member states are the most widely used disposal outlets despite their environmental drawbacks.

17.3 Mining waste

Waste from extractive operations (i.e. waste from extraction and processing of mineral resources) is one of the largest waste streams in the EU and many other countries. It involves materials that must be removed to gain access to the mineral resource, such as topsoil, overburden and waste rock, as well as tailings remaining after minerals have been largely extracted from the ore.

Some of these wastes are inert and hence not likely to represent a significant pollutant threat to the environment save for smothering of riverbeds and possible collapse if stored in large quantities. However, other fractions, in particular those generated by the non-ferrous metal mining industry, may contain large quantities of dangerous substances, such as heavy metals. Through the extraction and subsequent mineral processing, metals and metal compounds tend to become chemically more available, which can result in the generation of acid or alkaline drainage. Moreover, the management of tailings is an intrinsically risky activity, often involving residual processing chemicals and elevated levels of metals. In many cases, tailings are stored on heaps or in large ponds, where they are retained

Figure 17.4 Huge volumes of waste are generated during the mining and processing of sylvinite ore used to produce potassium chloride that is a mineral fertilizer used in agriculture. The picture shows "mountains" of waste near the town of Soligorsk, Belarus, untypical for the local landscape. This waste gravely affects the environment in the region.

Figure 17.5 The serious pollution of the Danube River caused by a cyanide spill following a damburst of a tailings pond in Romania in 2000.

by means of dams. The collapse of dams or heaps may have serious impacts on the environment and human health and safety. Examples of this are the accidents in Aberfan (Wales, 1966), Stava (Italy, 1985), Aznalcóllar (Spain, 1998), Baia Mare and Baia Borsa (Romania, 2000). Other likely significant impacts relate to the physical footprints of waste disposal facilities and resulting loss of land productivity, effects on ecosystems, dust and erosion.

These impacts can have lasting environmental and socio-economic consequences and be extremely difficult and costly to address through remedial measures. Wastes from the extractive industries have therefore to be properly managed in order to ensure in particular the long-term stability of disposal facilities and to prevent or minimize any water and soil pollution arising from acid or alkaline drainage and leaching of heavy metals.

A comprehensive framework for the safe management of waste from extractive industries at the EU level is now in place comprising:

Directive 2006/21/EC on the management of waste from the extractive industries (the mining waste directive).

Best Available Techniques reference document (BREF) for the management of tailings and waste-rock in mining activities; and an amendment of the Seveso II Directive (prevention and control of industrial accidents) to include in its scope the mineral processing of ores and, in particular, tailings ponds or dams used in connection with such mineral processing.

The pollution of the Danube River caused by a cyanide spill following a damburst of a tailings pond in Baia Mare, Romania, in 2000, as well as the accident that occurred in 1998 in Aznalcóllar, Spain, where a damburst poisoned the environment of the Coto Doñana National Park, have increased public awareness of the environmental and safety hazards of mining activities.

These accidents, like other similar ones, have in particular illustrated the significant environmental and health risks associated with the management of mining waste as a result of their volume and pollution potential.

UZWATER

This compendium is produced for a master level course in the UZWATER project. It consists of some newly written material as well as previously published texts extracted from freely available books, reports and textbooks on the Internet, dominated by publications from the Baltic University Programme. The sources used for each chapter is listed at the end of the chapter. The compendia of the Uzwater project are produced exclusively for Master students free of charge at the participating Universities and is not to be sold or be freely available on the Internet.

The UZWATER project is an EU TEMPUS project. It includes 8 universities in Uzbekistan and deals with university education for sustainable water managment in Uzbekistan. Uppsala University and Baltic University Programme is one of the six EU partners in the project. Lead partner is Kaunas University of Technology.

The main objective of the project is to introduce a Master level study program in environmental science and sustainable development with focus on water management at the eight partner universities in Uzbekistan. The curriculum of the Master Programme includes Environmental Science, Sustainable Development and Water Management.

The Sustainable Development unit will include the basic methods used in Sustainability Science, in particular introduce systems thinking and systems analysis, resource flows and resource management and a series of practical tools for good resource management, such as recycling, and energy efficiency.

The specific objectives of the project are:

- to establish study centers at the partner universities in Uzbekistan
- to improve the capacity to train master students with expertise to address the severe environmental and water management problems of the country;
- to support the introduction and use in Uzbekistan of modern education methods, study materials, and e-learning tools;
- to encourage international cooperation at the partner universities;
- to strengthen capacities to provide guidance to authorities and the Uzbekistan society at large;
- to ensure the visibility and promotion of the Master Programme through web pages, printed material and cooperation with society;
- to ensure continuity of the Master Programme and long-term support of the project outcomes at partner universities beyond Tempus funding.

http://uzwater.ktu.lt