10 Waste Reduction

10.1 The Waste Concept

10.1.1 The Waste Concept

Waste is spontaneously perceived as anything *useless* resulting from a process, or other activity, may be for a long time. When things are worn-out or destroyed to the extent they can no longer be used they are wasted. Even if we are familiar with this way to see waste, it is not so old. It is connected to industrial society, and even more so to mass-consumerism. In the older agricultural society almost everything was used over again, repaired, or – if not possible to use in the original way – used for something else or in the last resort used as a material. Material flows were more expensive, slower, and more cyclic. Our present environmental dilemma is due to large-scale linear flows. We need to find our way back to a new, or perhaps rather original, way to deal with waste.

Pollution may be seen as a form of waste. Pollution is waste, which threatens to escape into the environment and needs to be controlled and collected. It is sometimes called molecular waste. Thus pollution discussed in Chapters 8 and 9 – that is waste in liquid and gas streams – is also waste. The strategies, and to an extent technologies, dealt with in Chapters 8 and 9 are relevant also here. The waste discussed in this chapter will, however, be solid waste.

Just as pollution may be seen as a "lost money and resources", solid waste is the same. It is a lost resource which costs to deal with or get rid of. It is a sign of inefficiencies in the production process or shortcoming of a product, which has to be wasted.

It is obvious that we will never be able to completely get rid of waste, but it is also clear that we need to reduce it dramatically to become sustainable. This chapter is about that. A further discussion on waste is found in Book 3 of this series.

10.1.2 How to Produce Less Waste

A main route to a less wasteful society is *efficiency*. By being more careful we will be able to use our input resources more carefully. This is at the heart of the cleaner production approach, and is developed later.

However a production process, which will only produce products, is seldom a realistic goal. Some waste will always result. A second main approach is therefore to see waste as a *resource*. Waste is sometimes called "a useful resource but in the wrong place". So what to do with waste to turn it into a resource? There are many stories on ingenious ways to use waste: Some are well known, such as when the SO_X extracted

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Box 10.1 Waste Definitions – Dispose of and Discard

While the EU definition intends to be absolute, the Basel Convention definition is relative to national law and opens the debate between the meanings of the terms *discard* versus *dispose*. The lack of common understanding of the term discard is a major issue in debate about the waste definition.

Because of the ambiguity of the waste legislation, the European Court of Justice has been called upon to resolve a number of disputes, to interpret the waste definition. The Court has developed a number of key criteria for assisting in determining the existence of waste in practice and confirmed that the definition should not be interpreted restrictively, given that the EC Treaty confirms that Community environment policy is to aim at a high level of protection and is to be based, in particular, on the precautionary principle and the principle that preventive action should be taken. In addition, the Court has expressly stated that it is immaterial to the legal definition of waste whether a substance or object may have a commercial value or is capable of economic re-utilisation.

The Court has also underlined that the term discard must be interpreted in light of the aim of the Waste Framework Directive, pointing out that in that regard, the third recital states that: "The essential objective of all provisions relating to waste disposal must be the protection of human health and the environment against harmful effects caused by the collection, transport, treatment, storage and tipping of waste."

In addition, the Court has also identified a number of other criteria for determining the presence of waste, discussed principally in the context of production residue. In particular, the European Court has also made it clear that where special precautions must be taken when a residue is used, owing to the environmentally hazardous nature of its composition, this may be regarded as evidence of discarding.

A number of consequences follow from the application of the waste definition. When a material is considered to be waste, it is subject not only to the requirements and controls contained in the basic framework legislation of the Community pertaining to waste, namely the Waste Framework Directive, the Hazardous Waste Directive as well as the Waste Shipment Regulation, which implements the Basel Convention in the EU, including its provisions outlawing the export of hazardous wastes to non-OECD countries. It is also subject to a number of specific Community legislative instruments addressing particular treatment operations and waste streams.

Table 10.1 *Categories of waste according to EU Directive 75/442/EEC, Annex I.*

Q1	Production or consumption residue 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. residue 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	Residue of industrial processes (e.g. slags, still bottoms, etc.)
Q9	Residue from pollution abatement processes (e.g. scrubber sludges, baghouse dusts, spent filters, etc.)
Q10	Machining/finishing residue (e.g. lathe turnings, mill scales, etc.)
Q11	Residue from raw materials extraction and processing (e.g. mining residue, oil field slops, etc.)
Q12	Adulterated materials (e.g. oils contaminated with PCBs, etc.)
Q13	Any materials, substances or products whose use 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 above categories.

Source: EU Environmental Agency, 2003-03-09.

from a flue gas stream in a wet scrubber is transformed into gypsum. This is used for the production of gypsum boards for the construction industry. Other examples are less well known. Even if the construction/building industry most often produce large volumes of solid waste, it is not always so. A Japanese construction company at the site of house-building is sorting all "waste" into a total of some 60 fractions. All of this is used (Book 3, Chapter 10). A third case is the cement industry which uses waste and hazardous waste as fuel in the kilns. The Estonian Kunda Cement factory (Book 4, Case Study 1) even use the resulting alkaline ashes from the combustion to improve agricultural soil in Estonia, which is rather acid.

The more systematic use of waste as a resource relies on the so-called industrial symbiosis concept. (See further Chapter 11). Here all outputs from an industrial process are used in the next production process in a system of industrial plants. Fully developed examples of industrial symbiosis are not common. The best know case may be the Danish Kalundborg, but cases exits in many parts of the world. Most of them are in the agricultural sector where it seems to be easier to use waste, since it is organic material. This systems approach to production has been developed extensively by the Zero Emissions Research & Initiatives (ZERI). Here it is the careful use of all resources in a system that is in focus.

The long-term goal is to achieve the zero-waste plant. Here nothing is wasted. Everything is used for some purpose. The zero waste concept has been developed in practice e.g. by Zero Emissions Research at Graz University of Technology in Austria. Here the cleaner production approach has been in focus.

10.1.3 The Formal Definition of Wastes

In the formal definition of waste a more conventional view is taken. The definition of what is waste has been subject to intense debate in Europe. According to the EU Directive (75/442/EEC) as well as the international Basel Convention on control of "transboundary" movements of hazardous wastes from 1989 waste is defined as:

Substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law.

In the Council Directive 91/156/EEC, Art.1(a) this definition was amended:

Waste shall mean any substance or object in a waste category, which the holder discards or intends or is required to discard.

In the further discussion on the waste concept (Box 10.1) these notions of what is meant by discard and disposed of becomes central.

The waste categories referred to in the definition are listed in Table 10.1

10.1.4 Industrial Solid Waste

Industrial solid wastes is an important part of all waste produced in society. In most parts of Western Europe industrial waste is about 50% of all waste. In less rich societies, like the CEE countries, industrial waste is closer to 90%. In the list of solid waste categories (Table 10.1) industrial waste are found in categories Q6 to Q11. These will be further discussed below.

The largest amount of industrial waste is mining waste (Q11). The amount of waste as a percentage of the production of the resource extracted is very different for different mining processes and sources. Thus e.g. copper mining gives rise to a very large amount slag or over burden, typically more than 99% of the total, while in iron mining it is less. This waste is often landfilled at the site of extraction and forms large mounds. Sometimes this is rather harmless, as in the case of most iron mining waste. In other cases it is a serious environmental threat. Thus oil shale mining in Estonia has created mounds of waste, which leaks thousands of tonnes of wastewater containing resorcinol and other phenols, each year. The run-off thus has to be treated as toxic wastewater.

Residue from pollution abatement processes (Q9), such as calcium sulphate from desulphurisation of flue gases in a scrubber after combustion of sulphur-containing oil or coal may be large amounts, as well as ashes from incineration processes. Machining/finishing residue is most often the solid waste treated according to cleaner production strategies. It is also where the raw material utilisation may be improved.

10.2 Waste Management Strategies

10.2.1 The Waste Hierarchy

Waste management has a number of different concepts, which vary in their usage between countries or regions. The waste hierarchy classifies waste management strategies according to their desirability. The term *3 Rs*, or *Reduce-Reuse-Recycle*, has also been used for the same purpose. The waste hierarchy has taken many forms over the past decades, but the basic concept has remained the cornerstone of most waste minimisation strategies. The aim of the waste hierarchy is to extract the maximum practical benefits from products and to generate the minimum amount of waste.

Some waste management experts have recently incorporated a *fourth R*: *Re-think*, with the implied meaning that the present system may have fundamental flaws, and that a thoroughly effective system of waste management may need an entirely new way of looking at waste. Some *re-think* solutions may be counter-intuitive, such as a textile factory cutting fabric patterns with slightly more *waste material* left. The now larger scraps are then used for cutting small parts of the pattern, resulting in a decrease in net waste. This type of solution is by no means limited to the clothing industry.

Often the waste hierarchy is expanded to include a more complete series of alternative strategies for waste management. According to the sixth EU environmental action programme, 2001:

The EU approach to waste management is to prioritise waste prevention, followed by recycling, waste recovery and incineration, and finally, only as a last resort, land filling. The target is to reduce the quantity of waste going to final disposal by around 20% of 2000 levels by 2010 and in the order of 50% by 2050.

The waste hierarchy can be used most effectively as a guide to ensure that when developing a waste management policy or decision, an *integrated approach* is taken, where all options are considered.

10.2.2 Waste Minimisation or Source Reduction

This involves efforts to reduce hazardous waste and other waste materials by modifying industrial production. Source reduction methods involve changes in manufacturing technology, raw material inputs, and product formulation. As a consequence source reduction falls well within the concept of cleaner production and pollution prevention.

A practice that is being adopted in several countries either as voluntary measures or as legislation is the *Extended Producer Responsibility* (EPR) of holding the producer of a product responsible to some extent for the management of the waste products associated with that product. The producer is responsible to recover products that contain toxic and hazardous constituents which may present a threat to the safety of the community and which may place a burden on the end-of-life management of the product, for example motor vehicles, white goods, tyres, electronic equipment and mobile phones. This concept has developed in recent years as it is considered that an industry's responsibility for a product should not end with the sale of that product, but should extend to its reuse and/or disposal.

Figure 10.1 Abandoned TV-set. *An industry's responsibility for a product should not end with the sale of that product, but should extend to its reuse and/or disposal – Extended Producer Responsibility (EPR). (Photo: Morguefile/Pablo Gonzalez Vargas)*

10.2.3 Recycling

Recycling includes a number of recycling strategies, which may be described as;

Recovery as primary product or reuse, an example being the system of returnable beverage glass or PET bottles, in which every bottle is recovered and reused several times.

Material recycling is sometimes referred to as secondary recycling, where the waste is used to replace virgin raw material.

Recycled material can follow two major pathways: closed loop and open loop. In closed loop systems, recovered material and products are suitable substitutes for virgin material. In theory a closed loop model can operate for an extended period of time without virgin material. Of course, energy, and in some cases process material, is required for each recycling. Solvents and other industrial process ingredients are the most common materials recycled in a closed loop.

Open loop recycling occurs when the recovered material is recycled one or more times before its disposal. Many source separated industrial waste materials, as steel, aluminium, different plastic materials etc., are recycled in open loops. E.g. is scrap iron and steel sent to steel mills for re-processing. In many cases also post-consumer materials are recycled in open loops. The slight variations in unknown composition of such materials usually cause them to be downgraded to less demanding uses.

Some material also enters a cascade open loop model in which it is downgraded several times before the final disposal. For example, used white paper can be recycled into additional ledger or computer paper. If this product is then dyed and not de-inked, it can be recycled as mixed grade after use. In this form, it can be used for paper board or packing material. Ledger paper also enters an open loop system when it is recycled into tissue paper or other products that are directly discarded after use.

The popular meaning of recycling has primarily come to refer to the widespread collection and reuse of single-use beverage containers made of aluminium, glass, HDPE and PET after thorough cleaning. These types of containers may also be collected and sorted into common groups, so that the raw materials of the items can be recovered and used for production

Figure 10.2 Recycling bins. *Recycling is slowly making its way in all countries in the Baltic Sea region. In households a minimum of two fractions are required by law: organic waste and other. Today many households have on a voluntary basis six fractions; compostable, burnable, hard plastics for recycling, glass for recycling, paper for recycling, metal for recycling. (Photo: Morguefile/Kenn Kiser)*

of new containers or other products. Other common consumer items recycled in this way include steel food cans, and aerosol cans, glass jars, paper board cartons, newsprint, magazines and cardboard. Other types of plastic (PVC, LDPE, PP and PS) are also recyclable.

Recycling of material on molecular scale, also called tertiary recycling, is a more seldom applied principle, but in principle a possible way of utilising waste. One example that has been investigated is polymer recycling by processing polymers into the original monomers or other simple molecular compounds and then building new polymer molecules. One material that may be recycled this way is Poly-Ethylene-Tereftalate (PET), although it is still not economically feasible.

Resource utilisation or downgraded recycling. Instead of reusing the product or the waste material in a recycling material flow, the material is used for applications with less requirements regarding the purity and quality. An example of this is the use of recovered PET material for production of insulation material or for production of fleece fabric. Another example is the use of crushed glass as light-weight filling in road construction.

In principle also composting could be classed as downgraded recycling. By composting, organic material is converted into compost (humus or soil) that may be used for soil amendment and to replace commercial fertilisers in gardening and agriculture.

Energy recovery from waste is very common. Household waste as well as industrial waste consists to a large degree of combustible material as paper, wood and other organic material. This can be incinerated with energy recovery for heating and power production purposes. In Sweden 46% of all household waste is incinerated for district heating. The energy content of organic waste can also be recovered by digestion of the waste, whereby an energy rich biogas (a mixture of methane and carbon dioxide) is produced.

10.2.4 Waste Treatment

Waste treatment has as objective to convert waste to substances that either may be introduced into the natural material cycles or to be safely land filled. In order to be able to treat the waste it often has to be pre-treated. Pre-treatment primarily has the objective to prepare the waste for the final treatment. The more mixed or diluted a waste fraction is the more difficult it is to utilise or treat. Therefore a pre-treatment often involves a separation of the waste into fractions suited for a particular treatment method. The commonly used treatment methods can be subdivided into three groups.

Thermal treatment includes incineration and gasification or pyrolysis. In addition to energy recovery *incineration* reduces the waste volume by more than 90%. The ashes that are produced can be stabilised for safe land filling. In *gasification and pyrolysis* the waste is heated without access to air, contrary to the case of incineration. This means that the decomposition

Figure 10.3 Biological treatment of waste. *Anaerobic digestion of organic waste (anaerobic composting) produces methane, that can be recovered for energy purposes, and a soil residue often used in parks. (Photo: iStockphoto)*

Box 10.2 The Zero Emission Concept and Calculation of Total Environmental Costs

Emissions and costs

To be able to run a process (most often manufacturing, but in fact it could be any process) we need raw materials, operating materials, auxiliary materials, energy and labour force. These items normally represent constant streams.

During the process these different streams are treated mechanically, chemically or thermally. Due to different inefficiencies the amount of material that is part of the product in the end is less than what was fed into the process. These losses are called emissions. They can be defined in a very simple equation

Emissions = Input – Output

The output is the product. There are four different kinds of emissions: solid waste, fluidic waste, gaseous emissions, and energy losses (as heat, light etc).

These emissions correspond to a running cost. Thus reduced material and energy losses means a reduction of the running costs. If a reduction can be made it is not only a benefit for the environment but also a financial benefit for the company.

The meaning of zero emission

Zero emission refers to a production process that produces no waste at all. All resources are used for the product(s). That can be achieved in two different ways: either by the optimisation of the process itself, or by transforming the waste into a product that can be sold.

Zero can be defined in different ways:

- Absolute zero
- Analytical zero
- Zero impact

Absolute zero is the strictest definition of zero. For companies it means no emissions at all: no waste, no sewage water, no polluted air and no energy losses. It may be perfect for the future, but in our eyes it is presently neither necessary nor economically justifiable to try to achieve zero emission in the absolute sense. If an absolute zero emission is achievable or not depends on how the boundaries of the studied system is drawn. One could argue that unless the total entropy of the studied system is zero there will always be losses, mainly energy or exergy losses, in the environment outside the system boundaries (the 2nd law of thermodynamics).

Analytical zero means that the concentration of waste substances is below the point of detection by analytical methods. But analytical methods advance all the time and push the detection limits further down. Analytical zero is not well defined and not practical.

Zero impact is here understood as the concentrations of emissions are below the natural fluctuations in the environment. In this case one may assume that there is no impact. This is the definition of zero emission used here.

It should be noted that there is a similar notion on the input side. The use of renewable resources should be within the rates of their replenishment. For non-renewable resources one can take no more than what allows future generation to take the same amount.

Zero emissions and costs

Emissions mean lost input. The company has costs for buying resources and other inputs. To reduce the inputs means saving and costs reduction. By far the most common way to reduce costs is to reduce the number of employees. But to increase resource efficiency turns out to be a more interesting option. In Germany an average car manufacturing company has 67% of costs for materials, and 17% for personnel. These figures are similar for the manufacturing industry in general. Increasing personnel efficiency by some 3% yearly, which is typical for industry, thus only leads to some 0.5% improvements in the overall economy. Increasing resource efficiency by 3% would on the contrary be about 4 times better. The zero emissions concept is thus of interest to the company. It is also the solution for a sustainable company.

Using Environmental Management Accounting, EMA

EMA combines financial and physical data in a company and calculates its total environmental cost. The physical data includes material and energy input, material flows, products, waste and emissions. Financial data includes expenditures, costs, earnings, and savings related to the company activities.

The calculation of total environmental cost is not trivial. It is the combination of environmental protection costs, costs for wasted material, waste capital and wasted labour.

Environmental protection costs are defined as costs for prevention, disposal, planning, control, shifting actions and damage repair. Waste here has a double meaning. In addition to "normal" waste it also includes material that has been purchased and paid for but which was not turned into a marketable product. Waste therefore expresses production inefficiencies. The costs of waste materials, capital and labour have to be added up to arrive to a total corporate environmental cost and a sound basis for further calculations and decisions.

The total corporate environmental cost defined in this way should rather be described as the total direct environmental cost for the company. In order to get the overall environmental costs one would have to add the external environmental cost which e.g. consists of the environmental debt incurred due to the environmental damage caused by the emissions from the production of the company and the use of its products not paid for by the company or its customers either directly or via fiscal fees or taxes as well as the global loss of input resources not accounted for.

Waste in this context is used as a general term for solid waste, wastewater and air emissions and all other non-product outputs.

Environmental protection costs = costs for emissions treatment + costs for pollution prevention + costs for wasted material + costs of wasted capital + costs of wasted labour

How to arrive to environmental costs

For a company to calculate its total environmental costs its projects are compiled and described on the basis of existing data records, balance sheets, lists of accounts cost centre reports, list of assets etc. in the following way.

Step 1: List all environmentally relevant facilities in the company.

Step 2: Find the depreciation for these.

Continues on the next page >>

Table 10.2 *Worksheet for calculating total environmental costs.*

Environmental expenditure/costs and revenue/earnings									
Environmental media Environmental cost/expenditure categories	**Air/Climate**	**Wastewater**	**Waste**	**Soil/ground-water**	**Noise/ vibrations**	**Biodiversity/ Landscape**	**Radiation**	**Other**	**Total**
1. Waste and emission treatment									
1.1 Depreciation of related equipment									
1.2 Maintenance and operating materials and services									
1.3 Related personnel									
1.4 Fees, charges, taxes									
1.5 Fines and penalties									
1.6 Insurance for environmental liabilities									
1.7 Provision for clean up costs, remediation									
2. Prevention and environmental management									
2.1 External services for environmental management									
2.2 Personnel for general environmental management activities									
2.3 Research and development									
2.4 Extra expenditures for cleaner technologies									
2.5 Other environmental management costs									
3. Material purchase value of non-product output									
3.1 Raw materials									
3.2 Packaging									
3.3 Auxiliary materials									
3.4 Operating materials									
3.5 Energy									
3.6 Water									
4. Processing costs for non-product output									
Total environmental expenditures									
5. Environmental revenues									
5.1 Subsidies, awards									
5.2 Other earnings									
Total environmental revenues									

Box 10.2 Continues…

Step 3: Find number of hours of work and its costs at these facilities.
Step 4: Fill in all data in prepared excel sheets (Table 10.2).

In most cases the collection of all technical information takes much less time than the collection of financial data.

After this first round one should take a tour through the company to find environmentally relevant facilities forgotten in the first round. These data may be crucial for improvement through cleaner production approaches, but not for EMA accounting. As an example: total energy consumption of a plant is important for the EMA process, but temperature and pressure are not. However they may be crucial for finding cleaner production opportunities.

How to use the EMA results

The toolkit of EMA will allow the environmental managers to trace relevant costs in different records, to calculate total environmental costs, and to calculate the cost of an investment.

The whole procedure will identify the media or category of highest environmental costs but it will also show optimisation possibilities and cost saving potentials. The results should allow the company to:

- Estimate the total environmental costs.
- Verify the material balance equations.
- Discuss the existing information systems, weak points and potential improvements.

Most companies are not aware of their total environmental cost, what it is and what it comprises, labour, depreciation of facilities, etc. For example a company often believes that its wastewater costs equals the charges for wastewater discharges, which may be around 1 euro per m^3. However, depending on circumstances, the total costs for wastewater treatment may be 5-6 times higher.

A second result of the EMA process should be to identify where a company should start an optimisation process. For example it is not a good strategy to start energy saving if energy costs are just 10% of the total environmental costs and costs for solid waste is several times higher. In that case one should start to reduce solid waste.

Source: Mickael Planasch, Gernot Gwehenberger, Hans Schnitzer and Christoph Brunner, Graz University of Technology and Joanneum Research Institute for Sustainable Techniques and Systems, Graz, Austria, 2006. [See e.g. Planasch et al., 2006.]

of the waste takes place in a reducing atmosphere producing an energy-rich gas mixture of carbon monoxide, carbon dioxide, water vapour, hydrogen and methane in addition to a solid residue of tar and coke.

Biological treatment. Composting is the microbiological decomposition and stabilisation of organic material under aerobic conditions. In *digestion* the microbiological decomposition is carried out anaerobically, producing an energy rich biogas consisting of methane and carbon dioxide.

Chemical treatment is usually used for liquid waste fractions such as inorganic solutions from surface treatment and other metal solutions. *Chemical oxidation* is generally applied to de-toxify cyanide solutions from surface treatment industries. *Chemical reduction*, may be exemplified by the reduction of Chromium (VI) solutions to the less hazardous Chromium (III) form. *Chemical precipitation.* Metals are commonly separated from water solutions by chemical precipitation. The solid residue produced can either be utilised as raw material or land filled after stabilisation.

10.2.5 Land Filling

The last stage in the waste management hierarchy is to deposit the waste on a landfill. This alternative is a last resort and should, as expressed in most environmental policies and targets on international, national and local levels in communities and enterprises, be phased out or reduced as much as possible.

10.3 Reducing Waste through Cleaner Production Methods

10.3.1 Mining Waste

A large or even the largest, category of solid waste, the mining waste, often cannot be avoided but may have uses and thus not discarded as waste. The largest use is in construction work. Thus overburden from strip mining may be used in road constructions, but generally it is used for restoring the mining area when the ore body has been exhausted.

Alternative ways of extraction of metals may produce much less waste. An example is copper mining using biotechnological methods, so called *bioleaching*. In this approach microorganisms are used to extract the metal from sulphidic ores by treating the water passing though a mining field. Bioleaching is commercially used to process ores of copper, nickel, cobalt, zinc and uranium. In the process the microorganisms catalyse the oxidation of iron sulphides to create ferric sulphate and sulphuric acid. The ferric sulphate then oxidises the copper sulphide minerals, and the copper is leached by the sulphuric acid formed. In the related case of uranium leaching, the ferric sulphate oxidises tetravalent uranium oxide, which is insoluble in acid, to soluble hexavalent uranium oxide, which is then leached by the sulphuric acid.

An associated process is *biooxidation*, which is the oxidation of sulphide minerals associated with, but not necessarily part of the mineral of interest to be extracted. It is used in gold processing and in coal desulphurisation. In gold processing bacteria are used to oxidise an iron sulphide matrix in which the gold particles are embedded. The formed ferric sulphate is soluble and can be removed to make the gold available for cyanide leaching.

10.3.2 Recycling Polluted Residue

A typical cleaner production strategy is to take care of polluted material to make it useful. Thus contaminated solvents may be recovered e.g. by membrane separation and redistilled to be used over again, a common practice e.g. in pharmaceuticals production.

Contaminated oils may be recovered from e.g. waste liquids from petrol stations and separated from the wastewater by flotation and ultrafiltration and then used for energy recovery in waste oil incinerators.

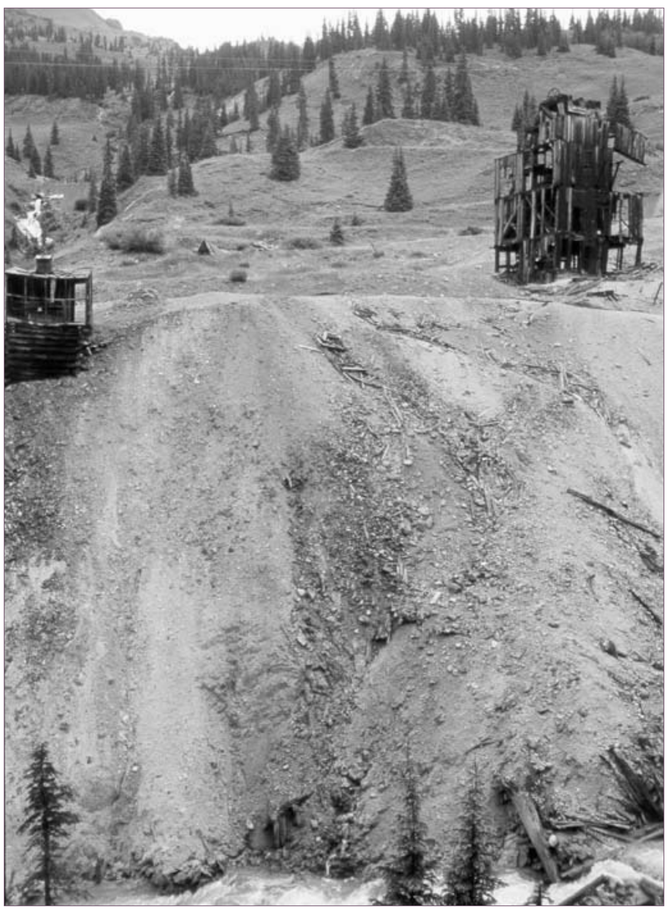

Figure 10.4 Mining waste. *Mining produces enormous amounts of waste, for example copper mining gives more than 99% waste. (Photo: U.S. Geological Survey)*

10.3.3 Efficient use of Materials

A process designed to use material in the most efficient manner reduces both material input and waste.

For example, a large American electronics company designed a flux-dispensing machine for use on printed circuit boards. This low solid flux (LSF) produces virtually no excess residue when it is applied, thus eliminating a cleaning step with CFCs and thereby simplifying operations. Performance of the boards produced with the new LSF was maintained, and the LSF helped this manufacturer reduce CFC emissions by 50%.

Material such as textile, paper or metal sheets used for cutting out pieces may be used more efficiently if the cutting process is optimised and carefully planned.

10.3.4 Resource Conservation

Resource conservation can reduce waste and directly lower environmental impact. A less material-intensive product may also be lighter, thus saving energy in distribution or use. For example, a fast-food franchise reduced material input and solid waste generation by decreasing the paper napkin weight by 21%. This did not lead to the use of more napkins.

10.4 Future Developments

During its first decade (1989-1999), the Basel Convention was principally devoted to setting up a framework for controlling the *transboundary* movements of hazardous wastes.

In 1999 the convention was revised and refocused. The result of this revision is that in the period 2000-2010 the Convention will focus its efforts on:

- Minimisation of hazardous waste generation.
- Active promotion and use of cleaner technologies and production methods;
- Further reduction of the movement of hazardous and other wastes;
- The prevention and monitoring of illegal traffic;
- Improvement of institutional and technical capabilities, especially for developing countries and countries with economies in transition;
- Further development of regional and sub-regional centres for training and technology transfer.

This means that the international priorities in waste management will be turned towards issues very central to Cleaner Production.

Study Questions

1. Describe why waste reduction is an important sustainability measure.
2. Discuss the two approaches of waste reduction, that is, efficiency and using waste as a resource.
3. Give the definitions of waste according to the EU Directives, and explain the concepts of dispose and discard waste.
4. Describe the waste hierarchy. Which measures are preferable and why?
5. What are the three Rs, and what is the fourth R, sometimes mentioned?
6. List the most important principles of waste reduction used in Cleaner Production work.
7. Explain the principles of recycling, including primary and secondary recycling, closed loop and open loop recycling, molecular scale recycling, and downgraded recycling.
8. Give three examples of successful waste reduction projects.
9. Describe briefly the zero emissions projects of ZERI and ZERIA.

Abbreviations

CFC	ChloroFluoroCarbon.
EPR	Extended Producer Responsibility.
HDPE	High Density PolyEthylene.
LDPE	Low Density PolyEthylene.
LSF	Low Solid Flux.
PET	PolyEthyleneTereftalate.
PP	PolyPropylene.
PS	PolyStyrene.
PVC	PolyVinylChloride.
UNEP	United Nations Environmental Programme.

Internet Resources

Secretariat of the Basel Convention, UNEP
http://www.basel.int

Council Directive 75/442/EEC on waste
http://eur-lex.europa.eu/en/index.htm

European Commission – Environmental Policies: Waste
http://ec.europa.eu/environment/waste/index.htm

Zero Emissions Research and Initiatives (ZERI)
http://www.zeri.org/

Graz University of Technology
– Zero emission research in Austria (ZERIA)
http://zeria.tugraz.at/index.php3?lang=en&sel=01ZERiA

European Commission
– Thematic Strategy on the Prevention and Recycling of Waste
http://europa.eu.int/comm/environment/waste/strategy.htm

International Solid Waste Association (ISWA)
http://www.iswa.org/

Resource Recovery Forum
http://www.resourcesnotwaste.org/

Chartered Institution of Wastes Management (CIWM)
http://www.ciwm.co.uk/pm/1

Air & Waste Management Association
http://www.awma.org/

Waste Management
http://www.wm.com/

U.S Environmental Protection Agency (EPA)
– Software for Environmental Awareness:
Household Waste Management
http://www.epa.gov/seahome/hwaste.html

EMARIC (Environmental Management Accounting Research and Information Centre)
http://www.emawebsite.org/about_ema.htm