

We are no longer able to think of ourselves as a species tossed about by larger forces – now we are those larger forces.

Bill McKibben, *The End of Nature*

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CHAPTER 8

Water and Industry

By

UNIDO

(United Nations Industrial Development Organization)

Key messages:

For the majority of the world's population, a thriving economy and improvement in the quality of life are closely linked to better access to consumer goods. Growing local industries create much-needed jobs, so people have more disposable income to spend on manufactured products. This often comes at the cost of increasing volumes of dumped solid waste, deteriorating water quality, and increased air pollution, when industry discharges untreated wastes onto land and into water and air. However, the linkage between industry and pollution is not inevitable. The purpose of this chapter is to show that manufacturing activities can be both clean and profitable. Indeed, industry can lead the way in pricing water at its true value and conserving high-quality water resources. Governance has an important role to play in creating the conditions that promote healthy and sustainable industrial growth.

- Industry is a significant engine of growth providing 48 percent of gross domestic product (GDP) in East Asia/Pacific, 26 percent of GDP in lower-income countries and 29 percent of GDP in higher-income countries, although this last figure is declining.
- It is possible to decouple industrial development from environmental degradation, to radically reduce natural resource and energy consumption and, at the same time, to have clean and profitable industries.
- A very wide range of regulatory instruments, voluntary initiatives, training and advice is available to help industrial managers improve water-use productivity and to reduce polluting emissions to very low levels. At the same time, these tools can aid production efficiency, reduce raw material consumption, facilitate recovery of valuable materials and permit a big expansion of re-use/recycling.
- Much industrial activity in middle- and lower-income countries is accompanied by unnecessarily high levels of water consumption and water pollution.
- Worldwide, the total rate of water withdrawals by industry is slowing, whereas the rate of water consumed is steadily increasing.

*Top to bottom:
Industrial site in
Grangemouth, Scotland*

*Dockside construction site
in the US*

*Water treated on site at a
rubber factory, Malaysia*





The total water withdrawal from surface water and groundwater by industry is usually much greater than the amount of water that is actually consumed

Part 1. Industry in an Economic Context

Industry is the engine of growth and socio-economic development in many developing countries. In the fast-growing East Asia and Pacific region, industry now provides 48 percent of the total gross domestic product (GDP), and this proportion is still increasing. In heavily indebted poor countries, the proportion of GDP provided by industry grew quickly from 22 percent to 26 percent between 1998 and 2002. In rich countries, by contrast, the proportion of GDP coming from the production of manufactured goods is slowly declining, currently providing some 29 percent of GDP, with services making up the bulk of the economy. Overall however, industrial production continues to grow worldwide, as economies grow (World Bank, 2003).

1a. Water use by industry

Water is used by industry in a myriad of ways: for cleaning, heating and cooling; for generating steam; for transporting dissolved substances or particulates; as a raw material; as a solvent; and as a constituent part of the product itself (e.g. in the beverage industry). The water that evaporates in the process must also be considered in accurate assessments as well as the water that remains in the product, by-products, and the solid wastes generated along the way. The balance is discharged after use as wastewater or effluent. The total water *withdrawal* from surface water and groundwater by industry is usually much greater than the amount of water that is actually consumed, as illustrated by the graphs in **Figures 8.1** and **8.2**. Industrial water use tends to be measured in terms of water withdrawal, not water consumption.

Following major growth between 1960 and 1980, water withdrawal for use by industry worldwide has pretty much stabilized. Industrial water withdrawal in Europe has actually been dropping since 1980, although industrial output continues to expand. In Asia, the growth in industrial water withdrawal was rapid up to 1990, and has since been growing much more slowly, despite the region's high growth in manufacturing output. As shown by these figures, the intensity of water use in industry is increasing in these regions, as is the value added by industry per unit of water used (see **Table 8.4** at end of chapter).

Once more information becomes available on environmental water flow requirements in many rivers and rainfed agriculture, a fuller picture may be presented of the allocation of water among all its various uses. It will also be necessary to analyse actual water use in terms of consumption by the various sectors (see **Figure 8.3**). The return flows from the different sectors to surface water and groundwater must be accurately depicted, with the inclusion of water reuse cycles (and water reclamation, see discussion below). Only then can a realistic water balance be prepared for a given river basin or country.

1b. Negative industrial impacts on the water environment

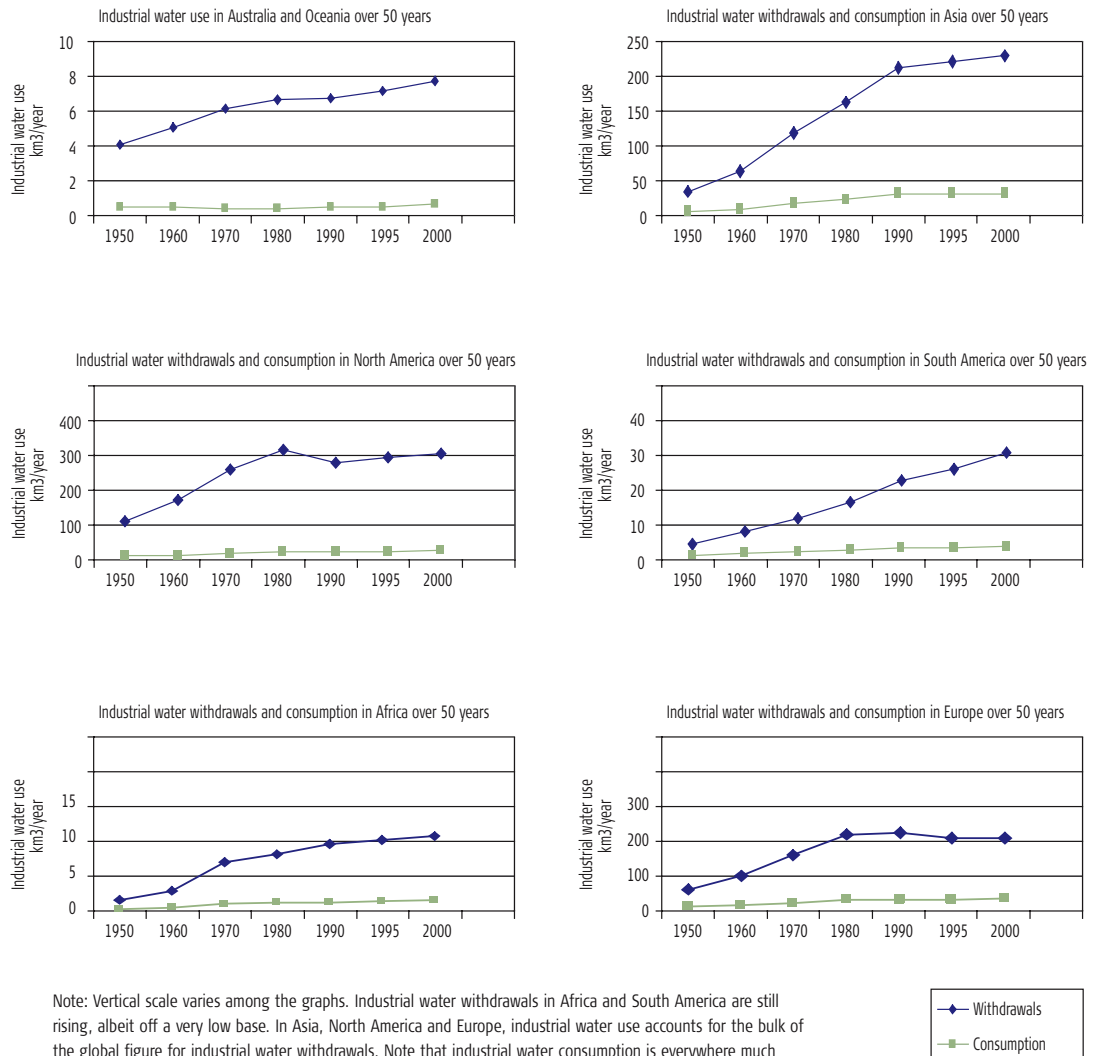
Frequently of greater concern than the actual volume of water used by industry is the negative impact of industry on the water environment. Water quality is deteriorating in many rivers worldwide, and the marine environment is also being affected by industrial pollution. How does this take place? Much of the water used by industry is usually disposed of 'to drain'. This can mean one of the following things:

- direct disposal into a stream, canal or river, or to sea
- disposal to sewer (which may be discharged, untreated, further downstream, or may be routed to the nearest municipal sewage treatment plant)
- treatment by an on-site wastewater treatment plant, before being discharged to a watercourse or sewer treatment in a series of open ponds.

There are many instances of water reclamation (treating or processing wastewater to make it reusable), where industrial effluent is not returned immediately to the natural water cycle after use. It can be recycled or reused directly on-site, either before or after treatment. The water may also be treated and then reused by other industries nearby or agricultural or municipal users, as well as for cropland irrigation or local parks and gardens. All these possibilities for water reclamation and reuse are dependent on the quality of the discharge and are discussed in more detail in Part 3. Reclaimed water that has been treated can also help to conserve the water environment by being injected to replenish underground aquifers or prevent salt-water intrusion or by being discharged into a drought-stricken wetland.

Of major concern are the situations in which the industrial discharge is returned directly into the water cycle without adequate treatment. If the water is contaminated with

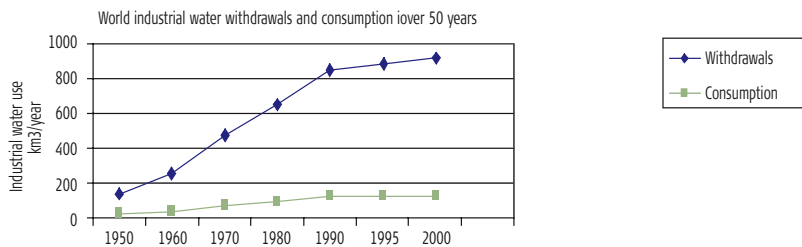
Figure 8.1: Trends in industrial water use by region, 1950-2000



Note: Vertical scale varies among the graphs. Industrial water withdrawals in Africa and South America are still rising, albeit off a very low base. In Asia, North America and Europe, industrial water use accounts for the bulk of the global figure for industrial water withdrawals. Note that industrial water consumption is everywhere much lower than the volume of water withdrawn.

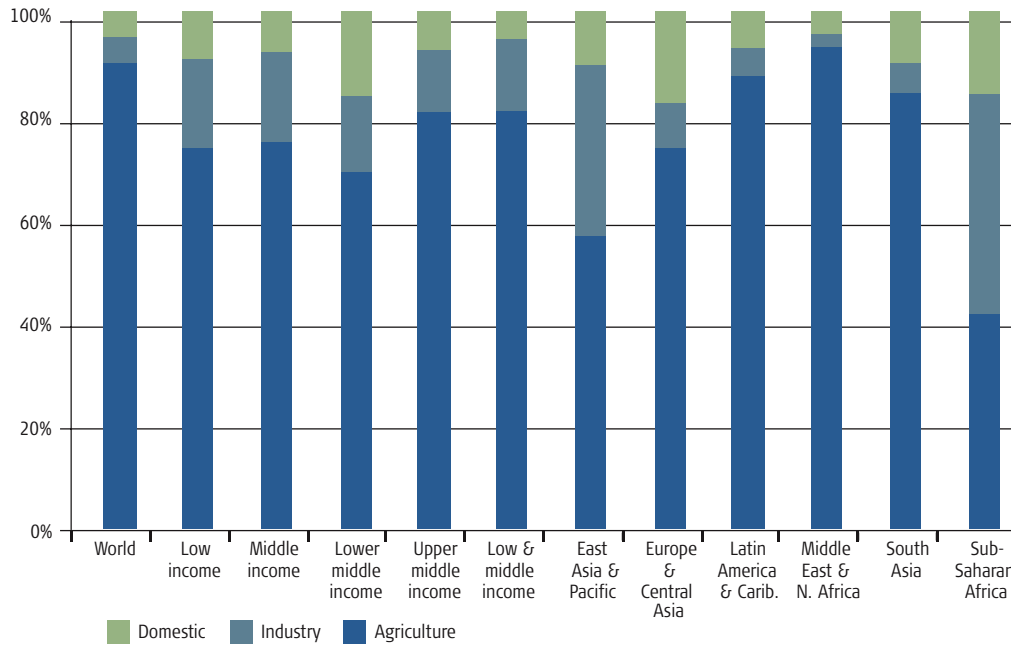
Source: Shiklomanov, 2000.

Figure 8.2: Total world industrial water use, 1950-2000



Source: Shiklomanov, 2000.

Figure 8.3: Water use by industry vs. domestic use and agriculture



Note: There is increasing competition for water among the various water use sectors in many river basins. If we compare water use (i.e. water withdrawal) by industry to water use by other sectors, namely agriculture and domestic use, it is clear that globally, industry uses only a fraction of the amount of water used by agriculture. However, in East Asia and the Pacific, industrial water use has grown to a significant proportion of total use, in line with its significance to the economies of those countries. In sub-Saharan Africa, although overall water use is low, the water used by industry is a larger proportion of the total, because more agriculture is rainfed, rather than irrigated. These data exclude rainfed agriculture from the calculations of water use, and do not include environmental flow requirements as a water use category. In many catchment areas and river basins, environmental needs have not yet been calculated (see **Chapter 5**).

Source: World Bank, 2002.

heavy metals, chemicals or particulates, or loaded with organic matter, this obviously affects the quality of the receiving water body or aquifer. The sediments downstream from the industrial discharge can also be contaminated. Water that has a high organic content (called the biochemical oxygen demand, or BOD) often appears cloudy or foamy, and is characterized by the rapid growth of algae, bacteria and slime (see **Figures 8.4 and 8.5** and **Chapter 5**). The growth of these organisms depletes the level of oxygen in the water. It is more difficult for fish, insects, amphibians and many species of aquatic plants to live and breed in such oxygen-depleted water. If the water discharged is still hot, this 'thermal pollution' may also affect the aquatic ecosystems downstream, which have to adjust to a temperature that is higher than normal (see also **Chapter 9**).

A much larger volume of water may actually be affected than the volume of the industrial discharge itself. Industries and water quality regulators in some places still

rely on the so-called 'dilution effect' to disperse contaminants within the water environment to the point where they fall below harmful levels. In areas where industries are growing fast and more industrial plants are coming on-stream with many newly created discharge points, this approach can quickly result in polluted rivers and reservoirs. The toxicity levels and lack of oxygen in the water can damage or completely destroy the aquatic ecosystems downstream as well as lakes and dams, ultimately affecting riverine estuaries and marine coastal environments. In international river basins, routine pollution and polluting incidents such as industrial accidents and spillages may have transboundary effects. Significant pollution sources in river basins, such as large industrial plants, may be termed 'hot spots' and prioritized for clean-up within a river basin management plan (see **Box 8.1**).

It is important to consider not only the level or concentration of individual substances, but also their



Above: An Ijaw child shows off the oil that has damaged the communal forest around her village in the Delta region of Nigeria. The fish catch has dropped dramatically as a result of oil spillage from a nearby extraction pipe

Below: Wastewater from bleaching cotton in a mill, Ndola, Zambia



combined effect. It is very expensive to monitor water quality for the presence of numerous chemicals, each of which must be tested for separately. By monitoring the populations of certain organisms, called indicator organisms (such as frogs, molluscs or certain insect species), it is possible to create a picture of how the water body is being affected over time. These ecotoxicological methods provide a more cost-effective way of assessing the impact of industrial discharges and are discussed in more detail in **Chapter 5** on ecosystems.

Direct human health impacts can result if the industrial discharge is located upstream of:

- a recreational bathing and swimming area or commercial, recreational or subsistence fishing grounds
- a point where farmers withdraw water in order to irrigate their crops

- a point where a municipality withdraws water for domestic use
- a point where people without a formal water supply withdraw water for drinking.

Many municipalities now find that the quality of the drinking water which they supply is compromised by industrial pollution. This raises water treatment costs for the water supply utility. Where the problem is variable freshwater quality, caused by irregular effluent discharges, the water treatment plant may not be able to cope adequately with the contaminants. In such cases the health of local people may be affected in the longer term, depending on the concentration and type of substances involved.

Two additional ways in which industries may more indirectly affect the water environment are through the following:

BOX 8.1: IDENTIFICATION, ASSESSMENT AND PRIORITIZATION OF POLLUTION 'HOT SPOTS'

The methodology for evaluating hot spots was developed within the framework of the Global Environment Facility (GEF) regional project preparing a Strategic Action Plan for the transboundary Dnieper River Basin, including areas of the three countries involved, namely Russia, Ukraine and Belarus. The objectives of the Strategic Action Plan are to facilitate the reduction of pollution in the river basin, and ultimately to contribute to the protection of the Black Sea.

As in many river basins in populated areas, there are thousands of pollution sources in the Dnieper River Basin. The Hot Spot methodology identifies, assesses and prioritizes the most significant sources of pollution, based on their impacts and characteristics. These include point sources, such as industrial and municipal effluents, and non-point sources, such as agricultural and urban runoff. Each contributes to human health risk and environmental degradation, including significant impacts to environmentally sensitive areas where biodiversity is threatened.

A multi-stage screening system, developed by the United Nations Industrial Development Organization (UNIDO), is used to identify priority hot spots. They are evaluated according to pollution control issues, water quality issues and biodiversity issues, as well as economic and employment criteria. Point sources of pollution are scored on a number of criteria under each of these general headings, which are then weighted according to their significance, before a total score is assigned. Non-point sources and areas that are difficult to characterize quantitatively (e.g. abandoned military facilities, or large tailings ponds) may still rank as hot spots but are described qualitatively, based upon the professional judgement of national experts. Finally, for a small group of priority hot spots, mitigation measures are proposed together with an estimation of implementation costs and a cost-benefit analysis.

An example of water quality issues scored includes the following criteria:

- location of nearest municipal drinking water withdrawal downstream
- influence of river quality on the nearest municipal drinking water withdrawal point
- population being supplied by river water within 25 kilometres downstream of the hot spot
- recreational bathing areas located near the hot spot
- other aquatic recreational activities near the hot spot
- any illnesses attributed to the recreational areas
- hot spot directly identified as the source of illnesses
- proximity of recreational fishing areas and sustainability
- proximity of commercial fishing areas and sustainability
- agricultural water utilization in proximity to the hot spot
- sediment quality
- proximity to national boundaries.

Source: UNIDO, 2003.

- The leaching of chemicals from solid wastes: The solid wastes generated by industrial activity may contain a quantity of contaminated water or other liquids, which gradually seep out once the waste is disposed of. In the rain (or in groundwater, if the waste is buried in a landfill), further chemicals may be leached or mobilized from the solid waste over time. This leachate eventually reaches a stream or an aquifer. Industrial dumpsites and municipal landfill sites, if not adequately constructed, are frequently found to generate such 'leachate plumes' that can be significant pollution hot spots.
- The atmospheric deposition of chemicals distributed through air and rain pollution: Some industries emit significant quantities of sulphur and nitrogen compounds (SO_x and NO_x) into the atmosphere. These may dissolve into raindrops, and fall as acid rain. Many streams, rivers and lakes in Europe are more acid than they would naturally be, due to this process. Other compounds such as dioxins and furans may also be released into the atmosphere from furnaces, and thereby enter the water cycle.

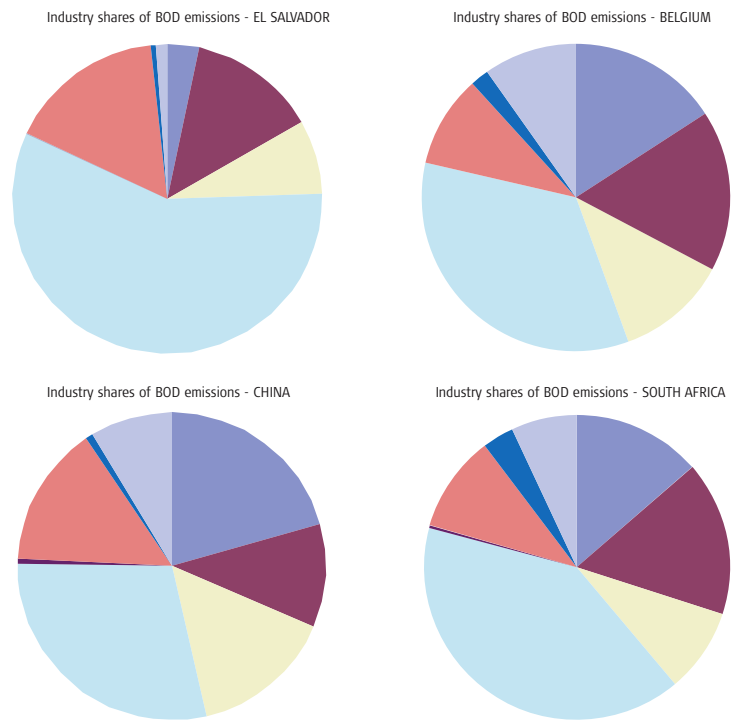
More detailed information on industrial pollution in Europe is available since the introduction of the European Pollutant Emissions Register. All factories in the European Union over a certain size are required to report their emissions. **Figure 8.5** shows figures on total organic carbon releases to water (a more accurate measure than the BOD data available). **Table 8.1** shows the amount of benzene, toluene, ethylbenzenes and xylenes being released annually to the water environment, both directly and indirectly. These toxic hydrocarbons are emitted by a range of industries, from oil refineries to pharmaceutical plants.

1c. Natech disasters

Natech disasters are a new disaster category, identified by the UN International Strategy on Disaster Reduction (UN-ISDR) as a technological disaster triggered by a natural hazard (see **Box 8.2**). In Europe, for instance, there are many vulnerable installations close to rivers or in earthquake-prone regions, which are vulnerable to flooding or strong tremors (see **Chapter 10**).

For example, the magnitude of an earthquake in Turkey that measured 7.0 on the Richter Scale in August 1999 triggered unprecedented multiple and simultaneous hazardous materials releases, wreaking havoc on relief operations assisting earthquake victims. In one incident, the leakage of 6.5 million kilograms (kg) of toxic acrylonitrile (ACN) contaminated air, soil and water,

Figure 8.4: Industry shares of biological oxygen demand (BOD), by industrial sector and in selected countries



Note: This figure shows the industry shares of organic pollution emissions (using BOD as an indicator), by industrial sector in selected countries. The data on BOD is the only pollution data available, and it is not very accurate as it is calculated indirectly from employment data in the various industrial sectors.



In less developed economies, such as in El Salvador, the food and beverage industry generates the majority of the organically loaded effluent. In developed countries such as Belgium, where the economy is more diversified, effluent from the food and beverage industry is still significant, but there is a wider spread of other contributing sectors. In China, the primary metals sector, chemicals and textiles contribute the lion's share. In all countries, the pulp and paper sector can be a significant polluter of the aquatic environment, if untreated effluent is released.

Source: World Bank, 2002.

threatening residential areas. Automatic foam sprayers were available at the industrial facility at the time of the earthquake, which would normally have contained the ACN release, but these were rendered useless due to a lack of water and power. These technological disasters posed additional health and psychological problems to an already devastated population. Hence current industrial risk management regulations should be carefully revised to ensure that this kind of 'natech' risk is being addressed.

Figure 8.5: Release of total organic carbon (TOC) directly or indirectly to water in thirteen EU Member States, 2003

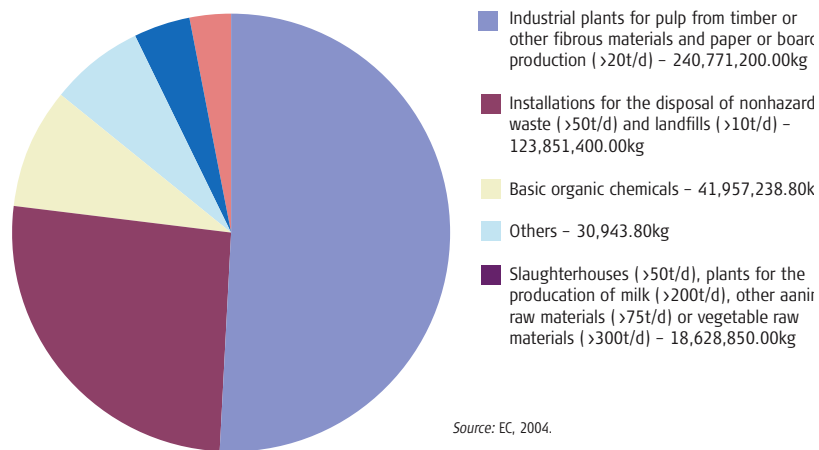
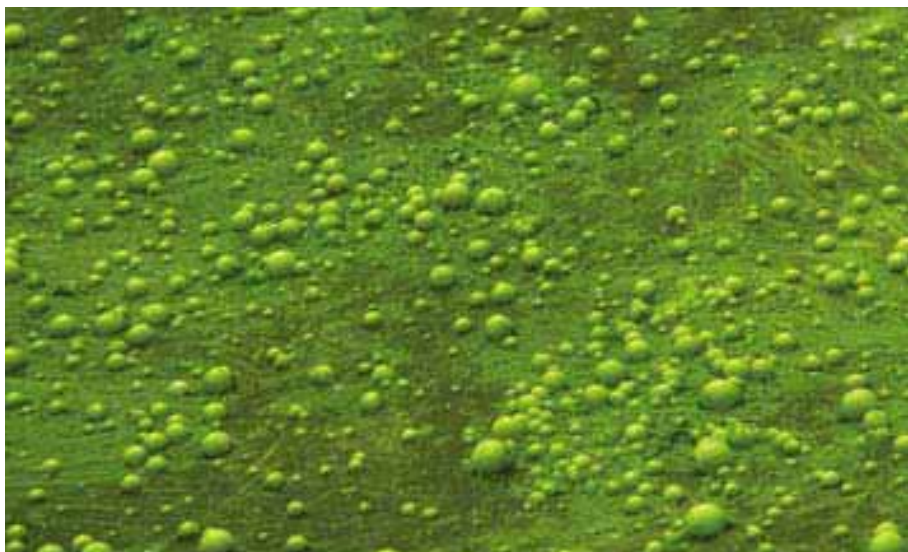


Table 8.1: Release of benzene, toluene, ethylbenzene and xylenes directly or indirectly to water in eight EU Member States, 2003

Activity releasing benzene, toluene, ethylbenzene and xylenes	Directly to water (kg/year)	Indirectly to water (kg/year)
Combustion installations (> 50 MW)	967	2,830
Mineral oil and gas refineries	67,486	880
Coke ovens	390	-
Coal gasification and liquefaction plants	1,020	-
Metal industry and metal ore roasting or sintering installations	16,080	8,080
Basic organic chemicals	40,328	127,158
Basic inorganic chemicals or fertilisers	57,996	-
Biocides and explosives	6,170	365
Pharmaceutical products	1,282	7,550
Installations for the disposal or recovery of hazardous waste (>10 tons/day)	2,300	2,136
Plants for the pre-treatment of fibres or textiles (>10 tons/day)	-	707
Installations for surface treatment or products using organic solvents (>200 tons/year)	-	3,773
Total	194,019	153,479

Source: EC, 2004.



BOX 8.2: INDUSTRIAL DISASTERS AROUND THE WORLD**The Tisza tailings dam disaster**

On 30 January 2000, a breach in a tailings dam released some 100,000 cubic metres (m³) of cyanide-rich tailings waste into the river system near Baia Mare in northwest Romania (see also **Chapter 14**). This spill released an estimated 50 to 100 tonnes (t) of cyanide, as well as heavy metals, into the Somes, Tisza and finally the Danube Rivers before reaching the Black Sea. Ice on the rivers and low water levels in Hungary delayed the dilution of the cyanide, increasing the risk to municipal water supplies. High concentrations of copper, zinc and lead, leached by the cyanide, compounded the problem. Impacts included:

- contamination and interruption of the drinking water in twenty-four locations, affecting 2.5 million people
- massive fish kill and destruction of aquatic species in the river systems
- severe negative impact on socio-economic conditions of the local population
- long-term reduction of revenue from tourism and canoeing
- drop in real estate prices.

The Red Rhine Incident

In 1986 a fire destroyed a chemical store in Basel, Switzerland, near the borders of France and Germany. Chemicals reached the water in the Rhine River through the plant's sewage system when huge amounts of water (10,000-15,000 m³) were used to fight the fire. The store contained large quantities of thirty-two different chemicals, including insecticides and

raw ingredients, and the water implications were identified through the presence of red dye in one of the substances, which turned the river red. The main wave of chemicals destroyed eels, fish and insects, as well as habitats for small animals on the riverbanks. The total eel population was destroyed for 500 kilometres (km) downstream, from Basel in Switzerland down to Loreley in Germany. It took three months after the incident for the contaminant concentrations to drop to normal values. As a result of new regulations and precautions put in place following this incident, the permanent chemical load in the Rhine has been reduced, and information systems on potential incidents improved.

Arsenic contamination from mines in Thailand

Past mining activities caused heavy arsenic contamination of groundwater and topsoil over a 40 km³ area in Nakhon Si Thammarat province, Thailand (see **Chapter 14**). The contamination was revealed in a study commissioned by the Japan International Cooperation Agency (JICA) in 2000. One conclusion of the study was that the contamination would last for the next thirty to fifty years. Testing of 1,000 samples showed arsenic contamination in some groundwater wells to be 50 to 100 times higher than the World Health Organization's guideline value for drinking water (0.01 milligrams per litre). Most people in the affected district stopped drinking well water in 1993, after the local health effects were found, and are now paying a very high cost for tap water.

Martin County, Kentucky, United States

On 11 October 2000, a coal tailings dam failed after the collapse of an underground mine beneath the slurry impoundment, and 950,000 m³ of coal waste slurry was released into local streams. About 120 km of rivers and streams turned an iridescent black, causing a fish kill along the Tug Fork of the Big Sandy River and some of its tributaries. Towns along the Tug were forced to turn off their drinking water intakes.

Nandan County, Guangxi Province, China

Also in October 2000, after a tailings dam failure, at least 15 people were reported killed and 100 missing. More than 100 houses were destroyed by the tailing wave downstream.

Sebastião das Águas Claras, Nova Lima District, Minas Gerais, Brazil

On 22 June 2001, the failure of an iron mine waste dam caused a tailings wave to travel at least 6 km. Five mine workers died in the incident.

San Marcelino, Zambales, Philippines

In August 2002, at the Dizon Copper Silver Mines, after heavy rain, the overflow and spillway failure of two abandoned tailings dams caused some tailings to spill into Mapanuepe Lake and eventually into the St. Tomas River. By 11 September, several low-lying villages had been flooded with mine waste: 250 families were evacuated; no injuries were reported.

Source: WHO, 2004.



Part 2. Governance Issues and Sustainable Development in Industry Regulation

Environmental governance is central to ensuring that growing industries undertake an acceptable and affordable level of pollution control and environmental management. This section discusses a number of international conventions and multilateral environmental agreements (MEAs) that exist in order to regulate industries, and in particular those dealing with hazardous and toxic chemicals (see Table 8.2). It is also important to note that voluntary systems go a long way towards demonstrating that industries can be both clean and profitable. Various voluntary approaches have been developed over time and are discussed later in this chapter.

The 'polluter pays principle', or the 3Ps, was first widely discussed at the 1992 United Nations Conference on Environment and Development held in Rio de Janeiro, Brazil (Rio Principle 16). The principle was endorsed by the attending country representatives, and was also adopted by the Conference of the Parties of the Basel Convention among others (see section 2a below). Under the Basel Convention, the 3Ps states that the potential polluter must act to prevent pollution, and that those who cause pollution must pay for remedying the consequences of that pollution. With the development of the concept of Cleaner Production (see section 3b below), the 3Ps now stand for Pollution Prevention Pays: in other words, good environmental management need not be simply an extra cost for a company to bear, but can actually improve production processes, save money and resources, and make the company more efficient, more profitable and more competitive in the global marketplace.

The World Summit on Sustainable Development (WSSD), held in Johannesburg, South Africa, in August 2002 proposed a Plan of Implementation, which makes a strong link between the related goals of industrial development, poverty eradication and sustainable natural resource management¹ (see **Box 8.3**). The Johannesburg targets proposed for industry to build on what was defined in Goal 7 of the Millennium Development Goals (MDGs) in 2000 by doing the following:

- ensuring environmental sustainability
- integrating the principles of sustainable development into country policies and programmes
- reversing the loss of environmental resources.

For countries adopting poverty-reduction policies, industrial growth is desirable in order to diversify their economy, create jobs and add value to primary products and raw materials being produced. However, it is very important that the necessary legal and institutional arrangements be in place to enable this growth to take place sustainably. Since water pollution can have significant transboundary effects, good environmental governance at the national level includes committing to international agreements and conventions on transboundary cooperation on shared waters (see **Chapter 11**).

2a. Best environmental practices and international standards for industry

Voluntary measures and self-regulation are the means whereby industries can demonstrate their commitment to improving the environment and monitoring their own performance. The extent of self-regulation tends to vary with the size of the enterprise, and the industrial sector in question. Consumers and media pressure can often influence the level of eco-awareness of companies in a particular sector. Women working through consumer organizations and environmental pressure groups have been particularly successful in bringing about good environmental practices in the companies making household products such as detergents. Eco-labelling is a growing practice whereby consumers can choose to buy certain products labelled to indicate that they are produced in a cleaner and more environmentally responsible way.

The international competitiveness of a company and its products in the global market is therefore often enhanced by its commitment to best environmental practices (BEP).² A company can show its high quality of self-regulation by seeking certification through ISO 14001, which is the current international environmental standard administered

1. See www.un.org/esa/sustdev/documents/WSSD_POI_PD/English/POIToc.htm

2. Best Environmental Practices (BEP) are guidelines that exist for all sectors of human society striving to co-exist with the natural environment, such as housing, infrastructure, industry and tourism. BEPs for industry include carrying out environmental impact assessments for new projects, environmental audits for existing projects and using best available technology.

by the International Organization for Standardization. By the end of 2002, nearly 50,000 companies in 118 countries had received this certification (see **Table 8.2**).

Some of the approaches to BEP, discussed below, have been made mandatory in national environmental law in some countries, but not in others. BEP can begin at the planning and design stage of a new industrial installation, with an environmental impact assessment (EIA), and be continued by putting in place an environmental management system (EMS) for the plant. Periodic or occasional environmental audits can be carried out during the plant's lifetime in order to assess the effectiveness of the environmental management system, and the plant's compliance with environmental regulations. The use of Best Available Technology (BAT) usually goes hand-in-hand with BEP (see **Box 8.4**).

Environmental Impact Assessment (EIA)

The EIA process is now required by law for new projects and significant extensions of existing projects in many countries. It covers a broad range of activities ranging from industrial to infrastructure projects. The process introduces procedural elements, such as the provision of an environmental impact statement and consultation with the public and environmental authorities, within the framework of development consent procedures for the activities covered.

...good environmental management need not be simply an extra cost for a company to bear...

BOX 8.3: INTERNATIONAL AGREEMENTS AND MULTILATERAL ENVIRONMENTAL AGREEMENTS (MEAs)

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal

Entered into force in May 1992. As of 28 May 2004, 159 states and the European Union were Parties to the Convention, which is an effective mechanism for addressing waste generation, movement, management and disposal. It plays a significant role in the safe management of chemicals. Recently, the Basel Convention joined with other existing international organizations in the creation of the Africa Stockpile Project, aimed at eliminating harmful stockpiles of pesticides on that continent. The Basel Convention is also working to create useful partnerships in areas as diverse as e-waste¹, biological and medical waste, and a global partnership aimed at addressing the stockpile of used oils in Africa.

The Rotterdam Convention on the Prior Informed Consent (PIC) Procedure for Certain Hazardous Chemicals and Pesticides in International Trade

A voluntary procedure from 1980 onwards, and is now mandatory in the 73 countries that are party to the Convention. This Convention entered into force in February 2004. A total of 27 hazardous chemicals are currently subject to the PIC Procedure. To put this into perspective, about 70,000 chemicals are currently on the market, with 1,500 new ones being added each year. This poses a significant challenge to governments, which must monitor and manage the use of these chemicals. The treaty helps countries to reduce the risks associated with the manufacture, trade and use of hazardous chemicals.

The Stockholm Convention on Persistent Organic Pollutants (POPs)

A global treaty, which entered into force in May 2004 and is designed to protect human health and the environment from persistent organic pollutants (POPs). POPs are chemicals that remain intact in the environment for long periods, become widely distributed geographically, accumulate in the fatty tissue of living organisms, and are toxic to humans and wildlife. They have been shown to cause cancer and to damage the nervous, reproductive and immune systems, as well as causing birth defects. At present, twelve hazardous chemicals, including DDT, dioxins and furans, are listed as POPs. In implementing the Convention, governments take measures to eliminate or reduce the release of POPs into the environment.

BOX 8.3: CONTINUED

The European Union Water Framework Directive (WFD) on Integrated River Basin Management for Europe

Adopted in October 2000, it coordinates the objectives of European water policy in order to protect all waters, including surface water and groundwater, using a river basin management approach. The WFD coordinates with all previous EU directives relating to water, including the **Integrated Pollution Prevention and Control Directive (IPPC)** of 1996, which addresses industrial installations with a high pollution potential. Such installations may only be operated if the operator holds a permit containing requirements for the protection of air, water and soil, waste minimization, accident prevention and, if necessary, site clean-up. These requirements must be based on the principle of **Best Available Techniques (BAT)** (see following section). The European Pollutant and Emissions Register, which has been compiled under the IPPC Directive, contains information on the emissions to air and water of nearly 10,000 industrial installations across Europe.²

The UNECE Convention on the Protection and Use of Transboundary Waters and International Lakes (UNECE Water Convention)

Intended to strengthen national measures for the protection and ecologically sound management of transboundary surface water and groundwater. It obliges Parties to prevent, control and reduce water pollution from point and non-point sources. More than 150 major rivers and 30 large lakes in the UNECE region run along or straddle the border between two or more countries. **The Convention entered into force in October 1996** and has been ratified by 34 countries and by the European Community. It is open for accession by all UN Member States.

The 1992 UNECE Convention on the Transboundary Effects of Industrial Accidents

Entered into force in April 2000, and 32 countries and the European Community are currently Parties to the Convention. This Convention cooperates with the UNECE Water Convention on issues related to the prevention of chemical accidents and the limitation of their impact on transboundary waters. In 2003 this resulted in the signing of the joint Protocol on Civil Liability and Compensation for Damage caused by Industrial Accidents on Transboundary Waters. The following work is being undertaken under both Conventions:

- An inventory of existing safety guidelines and best practices for the prevention of accidental transboundary water pollution³
- Safety guidelines and best practices for tailing dams, pipelines, and navigation of ships on rivers
- Alarm and notification systems
- International response exercises⁴
- Transboundary contingency planning.

1. E-waste is electronic and electrical waste including domestic computers and appliances.

2. The upgraded register, the European Pollutant Release and Transfer Register, should go online in 2009 and will then replace the present one, the European Pollutant and Emissions Register, EPER. Just like EPER, it will provide clear information about the level of specific pollutants, the quality of our local environment, emissions from specific industrial facilities and activities, and by country. But while EPER reports on 50 substances emitted to air and water, the PRTR will report on more than 90 substances released to air, water and land. The present register covers 56 industrial activities; the new one will cover 65. It will also have information on what the industrial installations do with their waste and waste water. The reporting cycle will be annual instead of every three years. What is more, the PRTR will compile reporting of pollution from diffuse sources such as road traffic, aviation, shipping and agriculture.

3. For more information see www.unece.org/env/teia/water/inventory.htm

4. For more information see www.unece.org/env/teia/response.htm

Table 8.2: Trends in ISO 14001 certification regionally and globally, 1997–2002

National standards institutes from individual countries have created the ISO 14000, which provides voluntary environmental management systems standards. The table below shows the number of companies in each region that have received the International Organization for Standardization (ISO) 14001 certification by December of any given year. Companies adhering to

the ISO 14001 implement environmental management systems, conduct environmental audits, and evaluate their environmental performance. Their products adhere to environmental labelling standards, and waste streams are managed through life cycle assessments. However, the ISO does not require companies to provide public reports on their environmental performance.

The number of companies with ISO 14001 certification globally increased more than tenfold between 1997 (two years after the introduction of the standard) and 2002. Europe and the Far East dominate the statistics, with 47 percent and 36 percent respectively of all companies certified worldwide. (ISO 14001 replaced ISO 14000 in 1995).

Regions	Number of companies with ISO 14001 certification					
	1997	1998	1999	2000	2001	2002
North America	117	434	975	1,676	2,700	4,053
Share in percent	2.64	5.50	6.91	7.32	7.35	8.20
No. of countries	3	3	3	3	3	3
Europe	2,626	4,254	7,365	11,021	18,243	23,316
Share in percent	59.24	53.94	52.21	48.13	49.62	47.14
No. of countries/economies	25	29	32	36	41	44
Central and South America	98	144	309	556	681	1,418
Share in percent	2.21	1.83	2.19	2.43	1.86	2.87
No. of countries/economies	5	12	14	18	22	21
Africa/West Asia	73	138	337	651	923	1,355
Share in percent	1.65	1.75	2.39	2.84	2.51	2.74
No. of countries/economies	10	15	21	25	29	31
Australia/New Zealand	163	385	770	1,112	1,422	1,563
Share in percent	3.68	4.88	5.46	4.86	3.87	3.16
No. of countries	2	2	2	2	2	2
Far East	1,356	2,532	4,350	7,881	12,796	17,757
Share in percent	30.59	32.10	30.84	34.42	34.81	35.90
No. of countries/economies	10	11	12	14	16	17
World total	4,433	7,887	14,106	22,897	36,765	49,462
Number of countries/economies	55	72	84	98	112	118

This rapid worldwide increase in the number of companies certified is accompanied by a dramatic rise in environmental awareness of managers and workers, because there is a substantial element of training and capacity-building involved in the certification process. This capacity-building and development of the environmental knowledge base necessarily goes hand-in-hand with the introduction of new management systems and performance yardsticks in these companies (see Chapter 13).

Source: www.iso.org/iso/en/prods-services/otherpubs/iso14000/index.html



Above: Polluted water due to discharge of refuse from a sugar-mill in Nosy Bé Dzamandzar, Madagascar

The EU commissioned eighteen case studies of the EIA process to be reviewed across Europe in order to investigate its effectiveness. This review showed that the EIA process improved the implementation of the project itself and ensured the protection of the environment. In the majority of the case studies, all participants confirmed that the EIA process had assisted in decision-making in one or more of the following ways:

- the quality of the project design was improved in 83 percent of the case studies
- key environmental issues were identified in 94 percent of the case studies
- higher standards of mitigation were achieved than would otherwise have been expected in 83 percent of the case studies
- environmentally sensitive areas were avoided through relocation or redesign of the project in 56 percent the of the case studies
- a better framework for preparing conditions and legal agreements to govern future operation of the project was provided in 72 percent of the case studies
- environmental concerns were incorporated from an earlier stage in the design process in 61 percent of the case studies
- better decision-making was achieved in at least 61 percent of the case studies, due to the following:
 - a more systematic and structured framework for analysis
 - more objective and credible information
 - increased rigour in evaluating environmental information.



BOX 8.4: BEST ENVIRONMENTAL PRACTICES (BEPs)**Environmental Management Systems (EMS)**

Aimed at achieving the organization's environmental policy, as defined by the top management. The system needs to describe various aspects, including setting responsibilities, defining environmental objectives, the means of achieving these, and the operational procedures, training needs, monitoring and communication systems that are to be used. The structure of an EMS is essentially an 'empty shell', within which the company defines its own unique ways of operating and establishing accountability. The most widely used EMS is that provided by the International Organization for Standardization within the ISO 14001 framework (see **Table 8.2**).

Environmental audits

These should be carried out periodically in order to assess the effectiveness of the management system in place and its conformity with the organization's environmental policy and programme. Quantitative technical audits can form part of this process, such as water and energy audits. An environmental audit must also assess the organization's compliance with relevant environmental regulatory requirements.

The European Union's Eco-Management and Audit Scheme (EMAS)

A voluntary scheme designed to promote continuous improvements of the environmental performance and compliance with all relevant regulatory requirements regarding the environment. To achieve this aim, industrial sites in Europe are required to use an environmental management system to monitor efficiency and to report on their achievements regarding environmental performance. They are also encouraged to seek ISO 14001 accreditation. EMAS statements are principally focused on improvements of environmental performance by describing the current environmental conditions and the operational aspects required at the site level to deliver continuous improvements in environmental performance. In regulatory

instruments, permits set the emission limit values for the company's activities. The licence stipulates a maximum load on the environment and what reduction of this load must be achieved. The EMAS environmental management system is an instrument that provides industries with a set of appropriate means for achieving an effective reduction in the load on the environment.

Best Available Technology (BAT)

The BAT concept is a useful standard-setting tool for emissions reduction in many industrial sectors. In the European Union (EU), however, the use of BAT is mandatory as part of the Integrated Pollution Prevention and Control (IPPC) Directive of 1996. Since 2000, all new industrial installations in the EU have been subject to the IPPC Directive and the BAT provisions. Imposing new and considerably tougher BAT rules on all existing industrial installations in the EU could jeopardize many European jobs, and therefore the IPPC Directive granted these installations an eleven-year transition period (i.e. to 2007). In many cases, BAT means quite radical environmental improvements, and sometimes it can be very costly for companies to adapt their existing plants to BAT.



'Best' is defined as that which is most effective in achieving a high general level of protection of the environment as a whole. 'Available' techniques are defined as those which can be implemented in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and benefits and whether or not the techniques are used or produced inside the country, as long as they are reasonably accessible to the operator. This includes both the technology used and the way in which the industrial installation is designed, built, maintained, operated and decommissioned. The following considerations should be taken into account when determining BAT:

- the use of low-waste technology
- the use of less hazardous substances
- the furthering of recovery and recycling of substances generated and used in the process and of waste, where appropriate
- comparable processes, facilities or methods of operation which have been tried with success on an industrial scale
- technological advances and changes in scientific knowledge and understanding
- the nature, effects and volume of the emissions concerned
- the commissioning dates for new or existing installations
- the length of time needed to introduce the best available technique
- the consumption and nature of raw materials (including water) used in the process and their energy efficiency
- the need to prevent or reduce to a minimum the overall impact of the emissions on the environment and the risks to it
- the need to prevent accidents and to minimize the consequences for the environment
- the use of information published by the EU or by international organizations.



Water can be saved either by cutting down on water input... or by water recycling and reuse...

Part 3. The Vision: Towards High Water Productivity and Zero Effluent Discharge

Both water quantity and quality need to be considered in the challenge of improving industrial water use. Where water *quantity* is concerned, it is useful to consider water productivity, in terms of the industrial value added per unit of water used (see Table 8.5 at end of chapter). The higher the water productivity, the greater the intrinsic value being placed on the water. In water-scarce regions, where there is competition for water among various users, water is likely to be allocated to the more highly productive uses. Industry achieves higher water productivity than agriculture, but as it is difficult to compare the water productivity of domestic use or environmental flow requirements, because the adequate data and economic instruments are not available to make such comparisons. Within industry, as in other sectors, it is important to strive towards greater water productivity.

Where water *quality* is concerned, zero effluent discharge is the ultimate goal, in order to avoid any releases of contaminants to the water environment. Zero effluent discharge entails water recycling, which also contributes to raising water productivity. If zero effluent discharge is not economically and technically feasible, there are some valuable intermediate strategies, which can be pursued to reduce pollution and to ensure that waste substances are recovered and water reused.

3a. Strategies for saving water and increasing industrial water productivity

Water auditing

Conducting a water audit of an industrial plant or manufacturing facility clearly shows where the water supplied to the plant is being used, how much is used in each process, and where it ultimately ends up. Rainwater that falls on the site, as well as the natural evaporation that occurs, should also be included in the audit. Once a water audit has been done, it is possible to draw a flow chart and show the water balance across the plant, or over individual units of the process. This is the first step in finding innovative ways to save water on an industrial site.

Water can be saved either by cutting down on water input, where it is being unnecessarily wasted, or by identifying water recycling and reuse opportunities, discussed in more detail below. On-site rainwater harvesting may also be considered, since this is preferable to allowing rainwater (which may have become contaminated) to simply run off into the stormwater system. Case studies from the same industrial sector can provide some ideas and general lessons on saving water, but each site needs to be audited and analysed individually.

Matching water quality to use requirements

In many instances, the water used in industry is of an unnecessarily high quality for the use to which it is put. The analogy in domestic water use is, for instance, using water of drinking quality in order to flush toilets or water the garden. Similarly, in industrial processes there are many applications where lower water quality could be used. This offers recycling opportunities. Often 50 percent or more of an industrial plant's water intake may be used for the purpose of process cooling, a need that can often be met with lower quality water. On the other hand, some industries (such as the pharmaceutical industry) require water of exceptionally high quality. In such processes, additional water treatment is carried out on the water received from the local water utility, or withdrawn from groundwater or surface waters, in order to further improve the water quality before it is used.

There are cases in industry where water is used inappropriately, where a completely different approach could be taken to save water in water-scarce areas. An example of this would be switching to using pneumatic or mechanical systems for transportation, instead of using water to move the products, as is often done in the poultry and other food industries.

Water recycling and on-site reuse

Water recycling is the primary means of saving water in an industrial application: taking wastewater that would otherwise be discharged and using it in a lower quality application (often after treatment). Each cubic metre (m³) of water that is recycled on-site represents one cubic metre that will not have to be withdrawn from a surface water source or from groundwater. Water can even be used many times over. In such cases, where, for instance, a

The most common uses of reclaimed water are industrial cooling and power generation, followed by boiler feed and quenching

given cubic metre of water is used ten times in the process (a 'recycle ratio' of ten to one), this represents 9 m³ that are not withdrawn from a freshwater source. Increased water savings can be made by raising the recycle ratio. The industrial water productivity of the product is thereby also greatly increased, as far less freshwater is used to produce the same quantity of product.

The way in which water recycling is done on-site must be governed by the principle of matching water quality to use requirements, as mentioned above. This is dependent on the nature of the manufacturing process, as well as on the degree of wastewater treatment carried out on the site. Processes such as heating, cooling and quenching are the most common applications for lower quality water. It can also be used as washdown water, and for site irrigation.

A second consideration in recycling industrial water is the cost of treating the wastewater to the required level, including the cost of new or additional pipes and pumps, as compared to the cost of 'raw' water supplies (freshwater). Where the quality of freshwater is declining locally, or where freshwater supplies are becoming unreliable due to water scarcity in the region (droughts or falling groundwater levels), on-site industrial water recycling becomes an increasingly attractive option. On-site

water recycling can be regarded as a component of industrial risk management, since it contributes to reducing the risk related to the unreliability of freshwater supplies.

For example, the micro-chip manufacturer, Intel, established the Corporate Industrial Water Management Group to improve water use efficiency at its major manufacturing sites, which use large amounts of highly treated water for chip cleaning. The group includes representatives from fabrication sites, corporate technology development experts, and regulatory compliance staff. Intel's initial goal was to offset by 2003 at least 25 percent of its total incoming freshwater supply needs by using recycled water and installing more efficient systems. In 2002, the company exceeded this goal by achieving 35 percent water savings through recycling water and efficiency gains.

Using reclaimed water

A more indirect means of recycling water occurs when an industrial enterprise reuses the wastewater produced by another industrial plant close by (with a treatment step in between, if necessary). Again, the principle of matching water quality to use requirements must be followed. The availability of wastewater, when needed, and its variability in terms of quality also need to be considered. For instance, an industrial plant could use wastewater from a

BOX 8.5: DEFINITIONS OF WATER RECLAMATION, REUSE AND RECYCLING

'Water reclamation', 'reuse' and 'recycling' should not be used interchangeably. In the wastewater treatment industry, the following definitions are used:

Water recycling normally involves only one use or user, and the effluent from the user is captured and redirected back into that use scheme. Water recycling is predominantly practised by industry.

Wastewater reclamation is the treatment or processing of wastewater (industrial or municipal) in order to make it reusable.

Reclaimed water is treated effluent suitable for an intended water reuse application.

Water reuse is the use of treated wastewater for beneficial purposes such as agricultural irrigation and industrial cooling. Water reuse can be done directly or indirectly.

Direct water reuse requires the existence of pipes or other conveyance facilities for delivering reclaimed water.

Indirect water reuse is the discharge of an effluent to receiving waters (a river, lake or wetland) for assimilation and further withdrawals downstream. This is recognized to be important and can be planned for, but does not constitute direct water reuse.

Water recycling and reuse has far-reaching benefits in industries beyond the mere requirement of complying with the effluent discharge permits:

1. Reduction in freshwater withdrawal and consumption
2. Minimization of wastewater discharge by reclaiming wastewater, thereby reducing clean-up costs and discharge liabilities
3. Recovery of valuable by-products
4. Improvement of the profit margin by cost reduction
5. Enhancement of corporate image, public acceptance and environmental responsibility.

Source: Asano and Visvanathan, 2001.



Above: This golf course in Arizona, US, is watered with recycled water from the city of Page

nearby municipal sewage treatment plant. The result is usually called reclaimed water and is sold to industry by municipalities in many countries, including Australia, South Africa and the US. The most common uses of reclaimed water are industrial cooling and power generation, followed by boiler feed and quenching. In such arrangements, the use of reclaimed water by industry eases the pressure on scarce water resources in the region.

In the metropolitan region of Durban, South Africa, an innovative public-private partnership has been supplying reclaimed water to industries since 1999 (see **Chapter 14**). The Southern Sewage Works of the Durban Metro Water Services treats over 100,000 m³/day of domestic and industrial effluent (through primary treatment only), prior to discharging it to sea through a long sea outfall. Projections showed that the capacity of the sea outfall would soon be reached, due to the growing population and industrial water discharges in the area. A secondary treatment plant with a capacity of 48,000 m³/day was built, which was allowed to discharge water into a canal that flows over the beach into the sea. A nearby paper mill then contracted to take 9,000 m³/day of the treated water. A local survey was undertaken, which found that further (tertiary) treatment would be required to sell reclaimed water to other industries in the area, which needed higher quality water than the paper mill. Since it was not economically feasible for the municipal water utility to construct and operate such a high-tech plant, the tertiary treatment works (which currently treats and sells up to 30,000 m³/day of reclaimed water to local industries) was built through a public-private partnership.

Agricultural irrigation and urban irrigation (of parks, sports fields and golf courses) are also major applications for reclaimed water, which is important since irrigation is usually the largest water user in any region (see **Chapter 7**). Israel currently reuses some 84 percent of its treated sewage effluent in agricultural irrigation. The World Health Organization has laid down guidelines for the use of reclaimed water in irrigation, as there may be health implications when reclaimed water is sprayed in the open (WHO, 2005). Reclaimed water can also be used to recharge aquifers, for instance to avoid saline water intrusion into the aquifer, or simply to augment the groundwater supply. In the Adelaide region of Australia, half of the city's water demand is met through reclaiming water by aquifer storage and recovery.

In construction applications, reclaimed water can be used for dust control, soil settling and compaction, aggregate washing and concrete production. Domestic applications for reclaimed water include fire fighting, car washing, toilet flushing and garden watering. Supplying reclaimed water in urban areas requires two sets of piping: one for potable water (drinking water) and the other for reclaimed water – termed 'dual reticulation'. The installation of dual reticulation is usually done in new housing developments, as laying it retrospectively may be prohibitively expensive. The Tokyo Metropolitan Government in Japan has long encouraged the fitting of new office blocks and apartments in Tokyo with dual reticulation (see also **Chapter 14**). There are even a few cities in arid regions, such as in Windhoek, Namibia, where reclaimed water is treated to a very high standard and then reused directly to augment the potable water supply.

Table 8.3: Wastewater treatment requirements as a function of end-use for industrial water supply

Industrial water use	Nitrogen and Phosphorus removal	Chemical precipitation	Filtration
Cooling tower makeup	Normally	Yes	Yes
Once through cooling			
– Turbine exhaust condensing	Sometimes	Seldom	Sometimes
– Direct contact cooling	Seldom	No	Sometimes
– Equipment and bearing cooling	Yes	Yes	Yes
Process water	Yes	Yes	Yes
Boiler feed water	Requires more extensive treatment; use of reclaimed wastewater generally not recommended		
Washdown water	Sometimes	Seldom	Yes
Site irrigation	No	No	Normally

Source: Asano and Visvanathan, 2001.

Both freshwater and reclaimed water can contain constituents that can cause problems, but their concentrations in reclaimed water are generally higher.

- **Scaling:** This refers to the formation of hard deposits on surfaces, which reduce the efficiency of heat transfer processes. Due to repetitive recycling of feed water in the cooling water, water lost by evaporation leads to increases in the concentration of mineral impurities such as calcium, magnesium, sodium, chloride and silica, which eventually lead to scale formation. Scale forming constituents can be eliminated using appropriate chemical precipitation techniques.
- **Corrosion:** Ammonia, which may be present in significant concentration in reclaimed municipal wastewater, is one of the prime causes of corrosion in many industrial water reuse installations. Dissolved oxygen and certain metals (manganese, iron, and aluminium) may also promote corrosion because of their relatively high oxidation potential. The corrosion can be controlled by adding chemical corrosion inhibitors.
- **Biological growth:** Slime and algal growth are common problems in reclaimed water due to a high nutrient content, which promotes biological growth. This growth can be controlled or eliminated by addition of biocides during the internal treatment process.
- **Foaming:** Associated with the presence of biodegradable detergents, foaming problems can be avoided by using anti-foaming chemicals.
- **Pathogenic organisms:** When reclaimed water is used in industry, the assurance of adequate disinfection is a primary concern for protecting the health of workers and plant operators. The most stringent requirement, similar to unrestricted reclaimed water use in food crop irrigation, would be appropriate if there exists a potential for human exposure to spray.

Minimizing virtual water in manufactured products

The concept of the virtual water trade has been mentioned in **Chapters 7, 11 and 12**, in relation to trade in crops and food products. The same concept applies in relation to manufactured products, where the virtual water of a particular finished product represents the volume of water that was used to produce it. This can be calculated

in two ways: either as m^3/t of product, or as m^3/dollar of added value. By looking at the imports and exports of each type of product, it is possible to calculate the virtual water flows into and out of the region. One can also calculate the industrial water productivity of various products and sectors, in terms of the industrial value added per unit of water used (see **Table 8.4** at end of chapter). In water-scarce regions, it makes sense to focus on the manufacture of products that use little water, and to therefore only export products with a high water productivity. This minimizes the amount of virtual water that is exported. Conversely, water-intensive products and products with low water productivity, such as aluminium and beer, should be imported into water-scarce regions, as this represents a way of indirectly importing water.

Better policy instruments and economic incentives

Industrial water management strategies that intend to minimize water consumption and wastewater generation, and thereby improve water productivity, can be either internal or external to the enterprise itself. Internal strategies are those measures that are required to be taken at a factory level in order for water consumption and wastewater generation to be controlled, such as water recycling. These measures can be taken more or less independently of external strategies.

External strategies, on the other hand, are measures that are required at the industry level in the context of local, regional or national industrial water management. Generally, the factory management does not control these strategies, although in certain cases some measures are required at the factory level in response. The nature and number of a particular type of industry present in a locality or a region can significantly influence these strategies. Some of these strategies are summarized as follows:

- national water recycling and reuse policies
- grouping of industries in a particular site (industrial parks) coupled with combined treatment methods and reuse policies
- rationing the water use within industry, so that each process uses a defined quantity of water
- applying economic instruments such as penalties, water charges, subventions, credits and grants.

...the virtual water of a particular finished product represents the volume of water that was used to produce it



National water conservation policy, also called water demand management, is the key factor in water recycling and reuse in industries. It forms an important component of national water efficiency plans. In some developing countries, industry is not charged for water nor for wastewater services; in other words, industrial water withdrawals and wastewater discharges are still free and unregulated. Both regulation and the imposition of stepped water tariffs according to the volume of water used are key instruments for governments to use in these situations (see **Chapter 12**).

Compliance with stringent effluent requirements can force industries to implement new water-saving technologies to reduce effluent discharges and prevent pollution incidents. Fines for non-compliance and the threat of closure for repetition of non-compliance can also significantly achieve higher recycling and reuse. Higher charges for raw water can be applied to industries using large volumes of water. An example can be seen in Singapore, which levies a 15 percent water conservation tax on operations using more than a specified amount. New factories using more than 500 m³ of water per month must apply for approval from the City Council during the planning phase. A fertilizer plant in Goa, India cut water demand by 50 percent over a six-year period in response to higher water prices. Dairy, pharmaceutical, and food processing industries in São Paulo, Brazil (see also **Chapter 14**), reduced water use per unit output by 62 percent, 49 percent and 42 percent, respectively (Kuylenstierna and Najlis, 1998).

Given proper incentives, it is generally found that industry can cut its water demand by 40 to 90 percent, even with existing techniques and practices (Asano and Visvanathan, 2001). However, water conservation policies need to be fair, feasible and enforceable. Economic incentives should be given to industry to comply with standards and policy and to reduce raw water intake and wastewater discharge. Such incentives could include subsidies for industries implementing innovative environmental technologies and financial and advisory support for industries that fund new research.

Pollution from a chemical factory upstream devastated fish farms along the Tuo River, a tributary of the Yangtze River, China

3b. Strategies and methodologies for reducing pollution: Paving the way to zero effluent discharge

No industrial plant operator sets out in the morning to pollute the environment. The objectives of a plant operator are to minimize production costs and to maximize the volume of production. Releases of pollutants into rivers and streams are carried out because this is typically a low-cost and low-tech option for waste and wastewater disposal. Frequently, once plant operators and managers become aware of the possibilities of cleaner production, the water and energy savings as well as the cost savings that can be made, their response is enthusiastic. In addition, the company as a whole can become more competitive in the global market by advertising its environmental policy and its strategies to reduce pollution. Some examples of how individual companies have benefited from implementing cleaner production methods are described in **Boxes 8.6** and **8.7**.

Strategies to reduce pollution include applying the principles of cleaner production in general. This is illustrated by a specific example of a UNIDO methodology for promoting cleaner production, the TEST (transfer of environmentally sound technology) strategy, which has been implemented in several river basins. Some of the specific processing techniques that can be applied to reducing water pollution on industrial plants include stream separation, raw material and energy recovery, and the reuse of waste and wastewater. End-of-pipe treatment technologies are also discussed briefly below, as these technologies are applicable both to recycling water, and to treating it prior to discharge back into the water environment. In the long run, the most desirable approach is that of aiming for zero effluent discharge, so that no industrial wastewater at all is discharged back directly into the environment.

Cleaner production

The principles of cleaner production include optimizing the use of resources used as inputs to the production process, such as raw materials, water and energy, and reducing to a minimum the generation of wastes. They are also concerned with the method of disposal of wastes and their impact on water, air and soil. A Cleaner Production Assessment (CPA) is a specific methodology for identifying areas of inefficient use of resources and poor management of wastes by focusing on the environmental aspects and impacts of industrial processes. This methodology (developed by UNEP) consists of the following five phases:

- **Phase I:** Planning and organization: obtain management commitment; establish a project team; develop policy, objectives and targets; plan the CPA.
- **Phase II:** Pre-assessment (qualitative review): prepare company description and flow chart; undertake a walk-through inspection; establish a focus.
- **Phase III:** Assessment (quantitative review): collect quantitative data; assess material balance; identify Cleaner Production opportunities; record and prioritize options.
- **Phase IV:** Evaluation and feasibility study: prepare preliminary evaluation; conduct technical evaluation; conduct economic evaluation; conduct environmental evaluation; select viable options.
- **Phase V:** Implementation and continuation: prepare an implementation plan; implement selected options; monitor performance; sustain Cleaner Production activities.

There is a network of National Cleaner Production Centres in twenty-seven countries, established by UNIDO, which assist in spreading the CPA methodology among companies in various industrial sectors. Many successful case studies of cleaner production are available, demonstrating how CPA can help companies become cleaner and more profitable.

Environmentally Sound Technologies (the TEST strategy)

Whereas CPAs are focused at the enterprise level, TEST is applied at a river basin level in order to scale up the benefits of clean production. The TEST strategy is a methodology that has been developed by UNIDO, which involves individual enterprises, national and local governments, and river basin organizations (see also **Chapter 14**). To date, it has been applied in the Danube and the Dnieper Basins with considerable success, helping to protect the Black Sea marine ecosystem (see **Box 8.8**). The methodology consists of the following aspects:

- identifying the pollution hot spots in the basin (see **Box 8.1**)
- introducing the principles of cleaner production and reducing the industrial pollution associated with certain enterprises, selected as demonstration sites, which are located at these pollution hot spots
- scaling up the TEST by training and equipping water managers, plant operators and local trainers and consultants with the principles and tools of the Cleaner Production Assessment (CPA), the Environmental Management System (EMS) and Environmental Management Accounting (EMA)
- supporting the relevant river basin organization in building awareness of the benefits of Cleaner Production and increasing industrial water productivity.

Given proper incentives, it is generally found that industry can cut its water demand by 40 to 90 percent...

BOX 8.6: CLEANER CHEESE PRODUCTION IN EL SALVADOR

A typical dairy company in El Salvador was using 10 litres (L) of milk and about 80 L of water in order to produce one kilogram (kg) of cheese. Nearly 9 L of whey were produced as a by-product and discharged into the wastewater. Whey is a highly concentrated organic liquid, containing proteins and lactose. Large dairy companies use ultra-filtration plants to produce pure lactose, additives for ice cream and other food products from this by-product. However, this technology is not affordable for small and medium-sized companies.

The solution proposed by the National Cleaner Production Centre in El Salvador was to process the whey in order to produce a marketable whey-fruit drink. Such drinks are available in the European market and are popular with consumers. No additional investment was required by the company in order to process the whey. The estimated benefits were found to include:

- 11.5 percent reduction in the volume of wastewater
- 40,000 milligrams per litre (mg/L) reduction in biochemical oxygen demand (BOD) level in wastewater
- 60,000 mg/L reduction in chemical oxygen demand (COD) level in wastewater
- US \$60,000 annual savings in wastewater treatment costs.

Other dairy companies in El Salvador are starting to produce this product, and similar programmes are being developed in Guatemala and Mexico.

BOX 8.7: CLEANER BEER PRODUCTION IN CUBA

Tinima Brewery is the second largest brewery in Cuba, producing 47,600 cubic metres (m³) of beer per year. In 2002, the National Cleaner Production Network responded to a request from the brewery's management for a cleaner production assessment (CPA) of the brewery.

Beer is produced by mixing, milling and boiling three main components: barley malt, sugar and water. This process produces a sugary liquid called wort, which is cooled, fermented and filtered in order to obtain the final product. A new technology was proposed to Tinima Brewery, in which the concentrated sugar syrup and water short-circuit the hot section and are added directly to the fermentation tank. This

means that the main volume of liquid does not pass through the hot section. The investment required was low, as these changes needed only some new pipeline arrangements.

This new technology was implemented at Tinima Brewery in 2003. The beer produced was found to be just as acceptable to consumers, and the technology is now approved for all breweries in Cuba. The following savings were achieved by Tinima Brewery as a result of the cleaner production technology:

- 74 percent reduction in cooling water consumption
- 7 percent reduction in total water consumption

- 11 percent reduction in the volume of wastewater
- 4 percent savings on sugar consumption (used as an additive to the beer)
- 3 percent savings on caustic cleaning solution consumption
- 50 percent savings on thermal energy consumption in the heating and evaporating stages
- 30 percent savings on thermal energy consumption in the cooling stages
- 12 percent savings in total electricity consumption
- 21 percent reduction in greenhouse gas emissions.

Source: UNIDO, 2004.

BOX 8.8: THE TEST STRATEGY IN THE DANUBE BASIN

The implementation of the TEST programme in the Danube River Basin began in May 2001 and was completed in December 2003, successfully introducing the TEST approach in seventeen companies in five countries (Bulgaria, Croatia, Hungary, Romania and Slovakia). The companies were identified as hot spots of industrial pollution, from various industrial sectors, including chemicals, food, machinery production, textiles, pulp and paper. Tangible results were achieved in terms of increased productivity and improved environmental performance. These results are used to show other enterprises in the basin that it is possible to reduce environmental impacts to acceptable levels while becoming more competitive.

There were 224 Type A (no cost or low cost) measures identified, of which 128 were implemented by the 17 participating enterprises. These were mostly 'good housekeeping' measures involving the following:

- process improvement (with small technological changes using existing equipment)
- raising the skills of operational staff
- revising laboratory procedures

- improving scheduling management and maintenance
- improving raw materials storage
- adjusting water consumption by reducing wastage and leaks, and improving process control.

There were 260 Type B (involving a relatively small investment with a short payback period) measures identified, of which 109 were implemented by the end of the project. The total investment undertaken by the 17 enterprises to implement the Type B measures was US \$1,686,704, while the estimated financial savings as a result of these measures are US \$1,277,570 per year.

It is interesting to note that the Bulgarian, Romanian and Slovak companies had the highest number of Type A and B measures identified. This can be explained by the fact that these companies used relatively outdated technology, thus many more measures could be identified to optimize the existing process. The environmental benefits were significant in terms of reduced consumption of natural resources (including

freshwater and energy), reduced wastewater discharges and pollution loads into the Danube River and its tributaries, as well as reduction of waste generation and air emissions. The total reduction in wastewater discharge into the Danube River Basin, achieved by the end of 2003 as a result of implementing Type A and B measures, was 4,590,000 m³ per year. Pollution loads in the wastewater were reduced in most of the companies, including chemical oxygen demand (COD), biochemical oxygen demand (BOD), oily products, total suspended solids, heavy metals and toxic chemicals.

Finally, 141 Type C (requiring a significant financial investment) measures were identified, of which 38 were approved by top management of the various enterprises for implementation. The total investment required for the approved Type C measures is US \$47,325,000 and they are scheduled for completion by 2007. The total additional reduction in wastewater discharges will be 7,863,000 m³ per year, with estimated annual savings by the companies of US \$5,362,000.

Source: UNIDO, 2004.

Stream separation

The principle of stream separation is a useful tool when assessing wastewater flows for treating the final discharge and when identifying flows of process water that may be recycled and reused. Wastewater containing a variety of contaminants is much more difficult and expensive to treat effectively than wastewater containing only one contaminant. Also, mixing a concentrated stream of effluent with a more diluted stream may result in much larger volumes of wastewater entering an expensive treatment process. The diluted stream alone may be suitable for discharge directly into a sewer, to be dealt with by a municipal wastewater treatment plant or may be suitable for on-site recycling for direct reuse in another part of the process. Treating the concentrated stream alone may become easier, because it may contain fewer contaminants and is likely to be cheaper, because the volume is much smaller. Now that a wide range of treatment technologies is available, stream separation may provide better and more cost-effective solutions in comparison to producing a single mixed effluent. The larger the enterprise, the more cost-effective this approach becomes. However, even small and medium-sized enterprises may benefit from considering stream separation.

Raw material and energy recovery from waste

An important aspect of reducing pollution is to look carefully at the solid and liquid waste generated by a given production process in order to calculate the quantities of unconverted raw material remaining in the waste streams. This unconverted raw material can potentially be reused. The feasibility of the recovery process can be assessed by determining the following:

- the cost of the separation process, which can recover the raw materials from the remainder of the waste
- the quantities of recoverable material
- the cost of the raw material
- the cost of waste disposal.

If the cost of the separation process is too high, or if the quantities of recoverable material are too small, material recovery becomes unprofitable. Similarly, very cheap raw materials and a low cost of waste disposal mitigate against the feasibility of the process.

Energy recovery may be possible in the same way from wastewater carrying waste heat. Once discharged, the waste heat becomes thermal pollution in the receiving water body. However, the heat could potentially be

recovered and reused in another part of the process, or indeed in another enterprise nearby, which requires lower grade heat. Indirect energy recovery can be done through a biological form of wastewater treatment, in which anaerobic bacteria break down organic matter in the wastewater and produce methane (biogas). The methane may then be used to fire a boiler or to generate electricity (see **Chapter 9**).

Reuse of waste

The recycling of glass, paper and various types of plastics are the best-known examples of waste reuse. However, there are many cases in industry where used solvents, oils, concentrated wastewater containing starch, or various solid wastes can be traded for their residual value and reused. One innovative industrial park in Cape Town, South Africa, has set up a voluntary Waste Register for the companies located within the park (see **Chapter 14**). Each company is required to log its waste production, the quantity and the type of waste, as well as the types of raw materials used as inputs and whether these may be reclaimed materials. The Waste Register may be searched on the industrial park's website, so that companies can identify sources that fit their requirements. This approach results in savings on raw materials and waste disposal costs for the companies involved.

Wastewater treatment technologies

These technologies are applicable both to recycling water and treating it prior to discharge back into the water environment. End-of-pipe treatment is often applied prior to discharging wastewater into the sewage system, as municipalities can charge industries for accepting their wastewater, with a rising tariff according to the concentration of the discharge. Some of the technologies mentioned below result in the recovery of energy or raw materials from the wastewater, such as anaerobic treatment, which produces biogas, and sulphate removal, which produces gypsum.

Today, there is a very wide range of treatment technologies available. Wastewater treatment technologies typically fall into two broad categories:

- physical/chemical treatment (e.g. settling, filtration, reverse osmosis, adsorption, flocculation, chlorination) and biological treatment (aerobic or anaerobic treatment which remove organic matter)
- other more specialized processes such as phosphate reduction and sulphate removal.

...there are many cases in industry where used solvents, oils, concentrated wastewater containing starch, or various solid wastes can be traded for their residual value and reused



There are also land-based treatment methods, such as treatment in flow through wetlands, and various types of contained lagoons (most of which are both aerobic and anaerobic). Matching the type of treatment to the contaminants in the wastewater (coupled with stream separation as mentioned above) results in the most cost-effective solution. There is no technological constraint on the quality of the water which can be achieved through treatment, although there are inevitably cost constraints.

Achieving zero effluent discharge

Zero Effluent Discharge is a key target for both reducing water withdrawal by industry, and reducing pollution to the water environment. All the effluent that would normally be discharged is recycled or sold to another user, using the principles of stream separation, raw material and energy recovery from waste, and reuse of waste, which have been discussed above.

Reducing the volume of effluent discharged back into the water environment by industry is essential to closing the gap between water withdrawal and actual water consumption, which was noted in the first section of this chapter. Once no more water is discharged from an

industrial installation, its overall water consumption will equal its water withdrawal from source. In practice, this means that water withdrawal by industry will gradually decline, as levels of water recycling increase, down to the point where withdrawal equals consumption. This process has already begun, as has been shown by the declining water withdrawal by industry in Europe over the past twenty-five years (see **Figure 8.1** above).

The city of St Petersburg, Florida, US, is the first municipality in the world to have achieved zero effluent discharge to its surrounding surface waters. Situated on a bay that is a major tourist attraction, the city has laid an extensive dual-reticulation system for reclaimed water. All the generated domestic and industrial wastewater is treated to a high standard. The reclaimed water is then reused for irrigation and industrial cooling applications by thousands of customers, accounting for nearly half of the city's water needs of 190,000 m³. By substituting reclaimed water for potable water in many applications, the city has eliminated the need for expansion of its potable water supply system until the year 2030. Equally important for the area, one sees no pollution of the beaches and marine ecosystems by municipal wastewater, and no unsightly sea outfalls.



Part 4. The 'Cradle-to-Cradle' Concept

There is a growing worldwide understanding that we need to find ways to make our industrialized society more conservative in its use of materials and resources. At present the uses of materials and other inputs to industrial processes (such as energy and water) are primarily linear. Resources are mined, products are manufactured, wastes are generated and then disposed of at the end of the process. Sooner or later, the products themselves end up as waste to be thrown away. By contrast, the 'cradle to cradle' concept is a vision of cyclical flows of materials: the materials that make up products are reused over and over again. This approach seeks to eliminate the whole concept of waste, bringing industrial production closer to the natural ecological process.

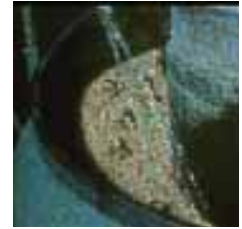
In 2002, this concept was put forward by William McDonough and Michael Braungart in their book, *Cradle to Cradle: Remaking the Way We Make Things*. They argue that there need to be two major flows of materials: one of biodegradable materials, termed 'biological nutrients', and one of non-biodegradable materials (such as metals and plastics) termed 'technological nutrients'. The earth's natural chemical and biological cycles will ensure the recycling of the biodegradable materials, while society needs to put in place the systems necessary for the complete recycling of the 'technological nutrients'. For the recycling of materials, it is important that the two flows be kept distinct, otherwise each cycle will progressively contaminate the other. Hence the sourcing of materials for use in industry and the design of products become crucial: each product must be easily consigned to one or the other of the nutrient flows at the end of its lifespan so that cross-contamination does not occur between the two cycles. The authors argue that manufacturers need to change from becoming suppliers of a product, to suppliers of a service. A customer would use a product for a certain period, after which the manufacturer takes it back and breaks it down, reusing all of its materials to create new products.

What the cradle-to-cradle concept means for water is a complex question, as water is an essential part of both the biological and the technological cycles. However, water recycling is clearly the key. The basic principle must be refraining from contaminating the water that is returned to the biological cycle with any 'technological nutrients', or non-biodegradable materials, metals and solvents. Ideally, water should recirculate either within the biological cycle, or within the technological cycle. Implementing zero effluent discharge to the water environment would ensure that once used by industry, water stay within the technological cycle, except for that

fraction that evaporates and is thereby returned to the biological cycle, free of contaminants. Preventing the atmospheric deposition of contaminants and the leaching of solid wastes into the water environment would also be essential to implementing the 'cradle-to-cradle' vision.

In the long term, the cradle-to-cradle vision could become the basis of almost all product design in manufacturing. This would result in a much cleaner and healthier world. Applications of the concept need to be found that can be implemented by industries without excessive cost in developing countries. This implies building both the necessary design capacity in those countries, and the capability to tap into global technology and information support networks. The experience of the companies that have already adopted the 'cradle-to-cradle' strategy shows that effective design not only generates positive externalities but can also make good business sense.

This chapter has largely focused on industry's impact on the water environment through its routine water withdrawal and wastewater discharge. However, solid waste disposal and air pollution by industry, as well as major industrial disasters, such as the Red Rhine incident, can also affect freshwater quality and thereby pose a risk to the water environment. Aquatic ecosystems in many places worldwide are being damaged or destroyed by industrial pollution, which in the case of fisheries has direct economic consequences. Many municipalities now find that the quality of the drinking water they supply is compromised by industrial pollution. This raises water treatment costs for the water supply utilities, which are then passed on to consumers through increased water rates. Where the problem is variable freshwater quality, caused by irregular effluent discharges, the water treatment plant may not treat the contaminants adequately. Hence companies requiring clean freshwater, as well as municipalities, are finding their water security



...a vision of cyclical flows... the materials that make up products are reused over and over again



Washing sugarbeets as they are unloaded at a sugar factory, Antois-Picardy River Basin, France

...industries often lead the way towards a more sustainable society by implementing water recycling and putting environmental management systems in place...

increasingly affected by water shortages and deteriorating water quality.

Industries therefore have a dramatic effect on the state of the world's freshwater resources, both by the quantity of water that they consume and their potential to pollute the water environment by their waste discharge. Yet industries often lead the way towards a more sustainable society by implementing water recycling and putting environmental management systems in place in their factories and offices. As discussed, there has been an exponential increase over the past decade in the numbers of industrial companies worldwide seeking certification with ISO 14001, the international environmental standard. This demonstrates many companies' commitment to being

environmentally responsible as well as profitable, enhancing both their corporate image and their competitiveness.

As stated by the WSSD Plan of Implementation, poverty eradication and sustainable natural resource management are strongly linked. For countries adopting poverty-reduction policies, industrial growth is highly desirable in order to diversify the economy, create jobs, and add value to primary products and raw materials being produced. However, it is important that the necessary legal and institutional arrangements be in place to enable this growth to take place sustainably, keeping in mind that environmental commitment can be a highly efficient tool for enhancing profitability and competitiveness.

Table 8.4: Industrial water productivity by country, 2000/01

Country	Industrial value added (IVA): 2001* (billion constant 1995 US \$) (1)	Industrial water use: 2000 (Km ³ /year) (2)	Population: 2000 (million) (3)	Industrial water productivity (IWP) (US \$ IVA/m ³) (4) = (1)÷(2)	IWP per capita (US \$ IVA/m ³ /c) (5) = (4)÷(3)
Algeria	23.21	0.80	30.29	28.97	0.96
Angola	4.84	0.06	13.13	86.13	6.56
Argentina	69.13	2.76	37.03	25.07	0.68
Armenia	1.19	0.13	3.79	9.18	2.42
Australia	107.29	2.40	19.14	44.70	2.34
Austria	82.15	1.35	8.08	60.85	7.53
Azerbaijan	1.02	4.77	8.04	0.21	0.03
Bangladesh	13.10	0.52	137.44	25.25	0.18
Belarus	5.76	1.30	10.19	4.44	0.44
Benin	0.40	0.03	6.27	15.04	2.40
Bolivia	2.25	0.05	8.33	46.86	5.63
Botswana	3.41	0.03	1.54	127.97	83.05
Brazil	239.36	10.65	170.41	22.48	0.13
Bulgaria	3.48	8.21	7.95	0.42	0.05
Cambodia	0.79	0.02	13.10	35.14	2.68
Cameroon	2.67	0.08	14.88	33.69	2.26
Canada	205.98	31.57	30.76	6.52	0.21
Central African Republic	0.23	<0.01	3.72	56.08	15.09
Chad	0.30	<0.01	7.89	93.97	11.92
Chile	26.29	3.16	15.21	8.33	0.55
China	593.70	161.97	1,282.44	3.67	<0.01
Colombia	25.24	0.40	42.11	62.36	1.48
Congo, Dem. Republic	0.86	0.06	50.95	14.66	0.29
Costa Rica	4.16	0.46	4.02	9.11	2.26
Côte d'Ivoire	2.40	0.11	16.01	21.79	1.36
Czech Republic	20.97	1.47	10.27	14.31	1.39
Denmark	44.90	0.32	5.32	138.59	26.05
Ecuador	7.18	0.90	12.65	7.96	0.63
Egypt	24.03	9.57	67.88	2.51	0.04

Table 8.4: continued

Country	Industrial value added (IVA): 2001* (billion constant 1995 US \$)	Industrial water use: 2000 (Km ³ /year)	Population: 2000 (million)	Industrial water productivity (IWP) (US \$ IVA/m ³)	IWP per capita (US \$ IVA/m ³ /c)
	(1)	(2)	(3)	(4) = (1)÷(2)	(5) = (4)÷(3)
El Salvador	3.39	0.20	6.28	16.89	2.69
Estonia	1.72	0.06	1.39	26.80	19.24
Ethiopia	0.77	0.15	62.91	5.30	0.08
Finland	53.22	2.07	5.17	25.66	4.96
France	430.02	29.76	59.24	14.45	0.24
Gabon	2.85	0.01	1.23	198.17	161.12
Germany	748.18	31.93	82.02	23.43	0.29
Ghana	2.04	0.08	19.31	26.52	1.37
Greece	28.18	0.25	10.61	114.44	10.79
Guatemala	3.53	0.27	11.39	13.20	1.16
Guinea	1.59	0.03	8.15	45.85	5.62
Honduras	1.32	0.10	6.42	13.63	2.12
Hungary	17.26	4.48	9.97	3.85	0.39
India	120.24	35.21	1,008.94	3.42	<0.01
Indonesia	94.42	0.56	212.09	169.18	0.80
Iran, Islamic Republic	29.51	1.69	70.33	17.50	0.25
Italy	332.94	16.29	57.53	20.44	0.36
Jamaica	1.95	0.07	2.58	28.08	10.90
Japan	1,889.94	15.80	127.10	119.62	0.94
Jordan	1.80	0.04	4.91	40.27	8.20
Kazakhstan	8.39	5.78	16.17	1.45	0.09
Kenya	1.32	0.10	30.67	13.60	0.44
Korea, Republic	285.64	3.05	46.74	93.66	2.00
Kyrgyz Republic	0.36	0.31	4.92	1.17	0.24
Lao PDR	0.59	0.17	5.28	3.46	0.66
Latvia	1.88	0.10	2.42	19.60	8.10
Lebanon	2.52	0.01	3.50	333.78	95.47
Lesotho	0.43	0.02	2.04	19.31	9.49
Lithuania	2.48	0.04	3.70	60.34	16.33
Malawi	0.28	0.05	11.31	5.90	0.52
Malaysia	48.65	1.90	22.22	25.58	1.15
Mali	0.81	0.02	11.35	49.92	4.40
Mauritania	0.31	0.05	2.67	6.34	2.38
Mexico	99.69	4.29	98.87	23.25	0.24
Moldova	0.78	1.33	4.30	0.59	0.14
Mongolia	0.26	0.12	2.53	2.06	0.81
Morocco	13.36	0.20	29.88	66.51	2.23
Mozambique	1.50	0.01	18.29	102.65	5.61
Namibia	0.94	0.01	1.76	73.34	41.74
Netherlands	119.90	4.76	15.86	25.17	1.59
New Zealand	15.85	0.20	3.78	79.26	20.98
Nicaragua	0.48	0.03	5.07	14.34	2.83
Niger	0.39	0.01	10.83	31.69	2.93
Nigeria	14.31	0.81	113.86	17.65	0.16
Norway	49.05	1.46	4.47	33.56	7.51
Pakistan	15.71	3.47	141.26	4.53	0.03
Panama	1.49	0.04	2.86	34.47	12.07
Papua New Guinea	1.65	0.03	4.81	51.24	10.66

For countries adopting poverty-reduction policies, industrial growth is highly desirable in order to diversify the economy



Table 8.4: *continued*

Country	Industrial value added (IVA): 2001* (billion constant 1995 US \$) (1)	Industrial water use: 2000 (Km ³ /year) (2)	Population: 2000 (million) (3)	Industrial water productivity (IWP) (US \$ IVA/m ³) (4) = (1)÷(2)	IWP per capita (US \$ IVA/m ³ /c) (5) = (4)÷(3)
Paraguay	2.61	0.04	5.50	61.90	11.26
Peru	17.08	2.03	25.66	8.42	0.33
Philippines	28.07	2.69	75.65	10.42	0.14
Poland	50.65	12.75	38.61	3.97	0.10
Portugal	36.71	1.37	10.02	26.87	2.68
Romania	12.32	7.97	22.44	1.55	0.07
Russian Federation	139.79	48.66	145.49	2.87	0.02
Rwanda	0.37	0.01	7.61	35.11	4.61
Senegal	1.42	0.06	9.42	24.32	2.58
Sierra Leone	0.17	0.01	4.41	24.86	5.64
South Africa	51.35	1.61	43.31	31.99	0.74
Spain	208.17	6.60	39.91	31.54	0.79
Sri Lanka	4.11	0.31	18.92	13.33	0.70
Sweden	81.68	1.61	8.84	50.67	5.73
Syrian Arab Republic	3.18	0.36	16.19	8.74	0.54
Tajikistan	0.70	0.56	6.09	1.25	0.21
Tanzania	1.07	0.03	35.12	42.31	1.20
Thailand	69.52	2.14	62.81	32.46	0.52
Togo	0.33	0.01	4.53	25.22	5.57
Trinidad and Tobago	3.46	0.08	1.30	41.98	32.44
Tunisia	7.04	0.07	9.46	105.03	11.10
Turkey	50.00	4.11	66.67	12.18	0.18
Turkmenistan	3.46	0.19	4.74	18.34	3.87
Uganda	1.34	0.05	23.30	29.40	1.26
Ukraine	21.62	13.28	49.57	1.63	0.03
United Kingdom	340.03	7.19	59.63	47.28	0.79
United States	2,147.80	220.69	283.23	9.73	0.03
Uruguay	5.32	0.04	3.34	147.69	44.26
Uzbekistan	2.79	1.20	24.88	2.33	0.09
Venezuela, Bolivian Republic	31.69	0.59	24.17	53.82	2.23
Viet Nam	10.89	17.23	78.14	0.63	0.01
Yemen	1.86	0.04	18.35	43.74	2.38
Zambia	1.11	0.13	10.42	8.45	0.81
Zimbabwe	1.58	0.12	12.63	13.15	1.04

*For some countries only 2000 statistics are available.

Note: Values for IVA and population have been rounded to two decimal places. Source: World Bank, 2001; FAO, 2003.

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Pacific Institute: www.pacinst.org

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Stockholm Convention: www.pops.int/

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UNEP Division of Technology, Industry and Economics: www.uneptie.org/

UNIDO: www.unido.org/

Unilever: www.unilever.com/environment/society/

World Resources Institute: www.wri.org/

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