1

Global Perspective of Wastewater Treatment

CHAPTER MENU

1.1 Global Wastewater Treatment Scenario

Natural water in contact with foreign matter during either industrial manufacturing processes or domestic use becomes polluted. Such polluted water is termed wastewater. The removal of excessively accumulated foreign matter from wastewater is known as treatment. As is well known, the rate at which we deplete and degrade our fresh aquatic resources poses a great threat to our future life-support system. The rise in human population exploits more natural resources and this is met through the growth of industries, urbanization, deforestation, and intensive agricultural practices. Industries and urban sprawl discharge waste into rivers, the deforestation process itself aggravates sedimentation transport into streams, and the use of chemicals contaminates groundwater through percolation and rivers and lakes through surface run-off.

All these sporadic degrading activities have led to gradual deterioration in the quality of surface and subsurface water. The loss of water quality is causing health hazards, death of human-beings, death of aquatic life, crop failures, and loss of esthetics. Keeping in mind these alarming global problems and the importance of environmental and nature protection, the 1972 Stockholm Conference on the Human Environment was the first of its kind and jolted the world into an awareness of environmental issues. A tangible result of that conference was the setting up of the United Nations Environment Program (UNEP) to serve as the conscience of the UN in matters concerning the environment. Twenty years later came the next landmark – the Earth Summit in Rio de

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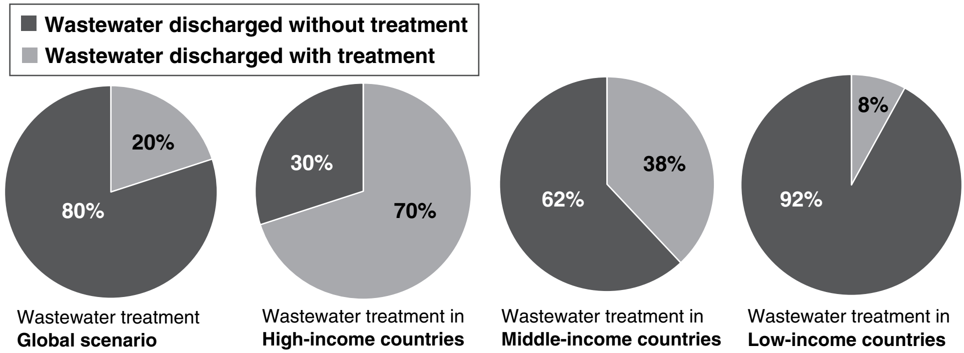

Figure 1.1 Global wastewater treatment scenarios.

Janeiro in 1992 – which exceeded everybody's expectations in terms of the number of attendees and scope of topics discussed. The Summit's message was broadcast to the world: "that nothing less than a transformation of our attitudes and behavior would bring about the necessary changes."

Globally, the practice of wastewater treatment before discharge does not seem to be good. On average, high-income countries treat about 70% of the municipal and industrial wastewater they generate [1]. That percentage drops to 38% in upper middle-income countries and to 28% in lower middle-income countries. In low-income countries, only 8% of wastewater undergoes treatment of any kind. These estimates support the often-cited approximation that, globally, over 80% of all wastewater is discharged without treatment. In high-income countries, the motivation for advanced wastewater treatment is either to maintain environmental quality or to provide an alternative water source when coping with water scarcity. However, the release of untreated wastewater remains common practice, especially in developing countries, due to lack of infrastructure, technical and institutional capacity, and financing (see Figure 1.1).

The discharge of untreated or inadequately treated wastewater into the environment results in the pollution of surface water, soil, and groundwater. The effects of releasing untreated or inadequately treated wastewater can be classified with regard to three issues:

- Adverse human health effects.
- Negative environmental effects due to the degradation of water bodies and ecosystems.
- Potential effects on economic activities: as the availability of freshwater is critical to sustain economic activities, poor water quality constitutes an additional obstacle to economic development.

According to the World Health Organization (WHO), water-related diseases kill around 2.2 million people globally each year – mostly children in developing countries.

1.2 The UN Sustainable Development Agenda for Wastewater

In September 2015, approximately 193 nation members of the United Nations General Assembly unanimously adopted "Agenda 2030" with a total of 17 Sustainable Development Goals (SDGs) to end poverty, protect the planet, and ensure prosperity for all (see Figure 1.2).

Figure 1.2 UN Sustainable Development Goals.

The establishment of SDG 6 (Clean Water and Sanitation) is aimed at ensuring availability and sustainable management of water and sanitation for all, reflecting the increased attention on water and wastewater treatment issues in the global political agenda. Agenda 2030 lists rising inequalities, natural resource depletion, environmental degradation, and climate change as among the greatest challenges of our time. It recognizes that social development and economic prosperity depend on the sustainable management of freshwater resources and ecosystems and it highlights the integrated nature of SDGs.

SDG 6 includes eight global targets that are universally applicable and aspirational. SDG 6 covers the entire water cycle, including: provision of drinking water (target 6.1) and sanitation and hygiene services (6.2); improved water quality, wastewater treatment, and safe reuse (6.3); water-use efficiency and scarcity (6.4); integrated water resources management (IWRM) including through transboundary cooperation (6.5); protecting and restoring water-related ecosystems (6.6); international cooperation and capacity-building (6.a); and participation in water and sanitation management (6.b).

SDG target 6.3 (to improve water quality, wastewater treatment, and safe reuse) focuses mainly on collecting, treating, and reusing wastewater from households and industry, reducing diffuse pollution and improving water quality. As per SDG 6 Synthesis Report 2018 on Water and Sanitation [2], ambient freshwater quality is at risk globally. Freshwater pollution is prevalent and increasing in many regions worldwide. Preliminary estimates of household wastewater flows from 79 mostly high- and high-middle-income countries show that 59% is safely treated. For these countries, it is further estimated that safe treatment levels of household wastewater flows with sewer connections and on-site facilities are 76 and 18%, respectively.

The degree of industrial pollution is not known, as discharges are ineffectively observed and only from time to time calculated and aggregated at national level. Although some local and modern wastewater is treated nearby, hardly any information is accessible and amassed for national and territorial evaluations. Numerous nations come up short on the ability to gather and analyse the information required for a full appraisal. Reliable water quality monitoring is fundamental to the direct needs for ventures. It is also important for assessing the status of aquatic ecosystems and the need for protection and restoration.

Increasing political will to tackle pollution at its source and to treat wastewater will protect public health and the environment, mitigate the costly impact of pollution, and increase the availability of water resources. Wastewater is an undervalued source of water, energy, nutrients, and other recoverable by-products. Recycling, reusing, and recovering what is normally seen as waste can alleviate water stress and provide many social, economic, and environmental benefits.

Managing wastewater by implementing global best practices of wastewater collection and treatment can support achievement of SGD target 6.3. Wastewater should be seen as a sustainable source of water, energy, nutrients, and other recoverable by-products, rather than as a burden. Choosing the most appropriate type of wastewater treatment system that can provide the most co-benefits is site specific, and countries need to build capacity to assess this. Reuse of water needs to take into account the whole river basin, as wastewater from one part of a basin may well be the source of supply for others downstream.

Managing wastewater and water quality also needs to include better knowledge of pollution sources. SDG reporting could support countries in aggregating wastewater subnational data and publicly reporting at the national level. This would include monitoring performance to ensure treatment plants are managed and maintained to deliver effluent suitable for safe disposal or use according to national standards, which may vary from country to country. Countries that do not have national standards and monitoring systems need to assess performance of on-site and off-site domestic wastewater treatment systems. Formalizing the informal sector through various policy instruments is needed to prevent excessive contamination. Incentives for the informal sector to be registered with the government could be accompanied by combined analysis of all wastewater sources and their relative contribution to health and environmental risks. This would enable countries to prioritize investments in pollution control that contribute most to achieving SDG target 6.3.

1.3 Global Market Size

The global market for water and wastewater technologies reached USD 64.4 billion in 2018 and should reach $83.0 billion by 2023, at a compound annual growth rate (CAGR) of 5.2% for the period 2018–2023 [3] (see Figure 1.3).

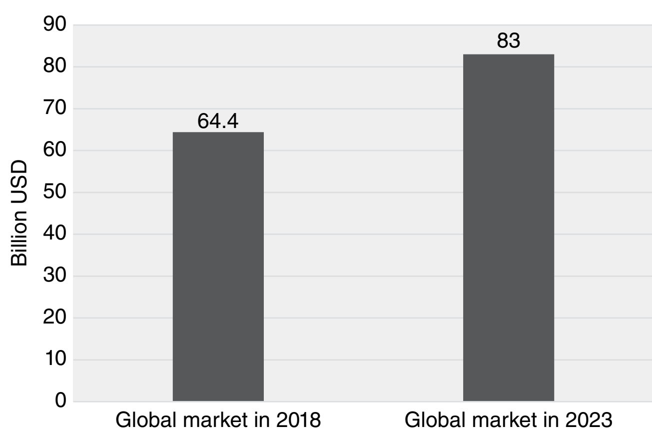

Figure 1.3 The global market size of water and wastewater technologies.

1.4 Global Best Practices

Treatment of wastewater has received steadily increasing attention across the world. During the manufacturing of industrial products, wastewater is generated at various stages which is very complex in nature and highly variable in quantity and quality.

Unless we adopt a structured approach toward collection, segregation, and treatment, it will be difficult to achieve the desired results. Best practices in wastewater treatment include:

- Reducing water consumption at source.
- Maximizing recycling and reusing during production.
- Promoting effluent identification, characterization, and segregation at source.
- Deploying sustainable technology to treat wastewater.
- Minimizing treated wastewater disposal.
- Eliminating incineration of wastewater.

See Figure 1.4.

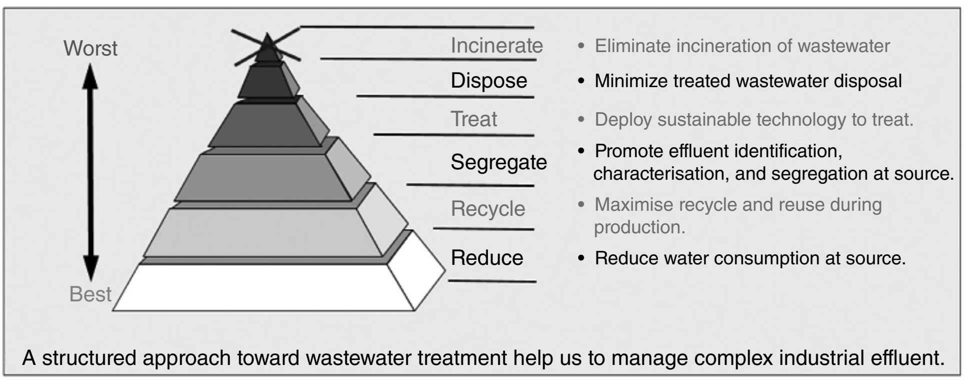

Figure 1.4 Best practices in wastewater treatment.

1.4.1 Effective Wastewater Treatment

Wastewater treatment is a complex process, and a properly operated wastewater treatment plant has many requirements. Below are six top considerations for effective wastewater treatment.

1.4.1.1 Discharge Standards

The first consideration is to understand the local discharge standards from the environmental authority. The authority may require that you submit a permit application or notice of intent that typically describes the sources, characteristics, and volumetric flow of your industrial wastewater discharge.

1.4.1.2 Wastewater Inlet Characteristics

We should understand the processes that produce waste streams and the wastewater characteristics of each stream. Review procedures for how products and reagents are combined to produce wastewater streams. Once we have sound knowledge of the characteristics and variability of the wastewater, we can design a treatment system and develop protocols to ensure continuous and compliant operation.

1.4.1.3 Wastewater Mass Balance

We should be familiar with the mass balance of how much water flows into a manufacturing plant and how many pollutants are in the wastewater. By conducting mass balances on all the constituents, a thorough understanding of the process can be obtained, leading to the optimal performance of the system. Flow rate is the most critical factor when calculating the capacity of a wastewater treatment system.

1.4.1.4 Wastewater Segregation

A structured approach toward wastewater treatment help us to manage complex industrial effluent. The best way to manage complex and variable industrial wastewater is through wastewater stream identification, characterization, and segregation (see Figure 1.5). The all-incoming effluent stream should be identified and segregated into green, yellow, and red streams. The green stream may consist of all the wastewater stream having total dissolved solids (TDS) < 5000 ppm and chemical oxygen demand (COD) < 10 000 ppm. The yellow stream may consist of all the wastewater stream having TDS < 100 000 ppm and COD < 20 000 ppm. The red stream may consist of all the wastewater stream having TDS > 100 000 ppm and COD > 20 000 ppm. After stream identification and segregation, the green stream may be treated with biological treatment technologies such as an activated sludge process or a moving-bed biological reactor; the yellow stream may be treated with forward osmosis (FO), Scaleban, or OH radical technology; and the red stream may be treated with multi-effect evaporation technology or any other appropriate evaporation technology.

Green stream	Yellow stream	Red stream
TDS<5000 ppm COD<10 000 ppm	5000<TDS<100 000 ppm COD<20 000 ppm	TDS>100 000 ppm COD>20 000 ppm
Biological treatment is best treatment solution for green stream effluent	Advanced oxidation and forward osmosis are best treatment solutions for yellow stream effluent	Advanced close evaporation is best treatment solution for red stream effluent

Figure 1.5 Wastewater stream segregation.

1.4.1.5 Sustainable Technology

We should use sustainable wastewater treatment technologies that consume less power and chemicals, generate less hazardous solid waste, and use minimum manpower. Use of sustainable wastewater treatment technology is the best opportunity for industries to drive smarter innovation and efficient wastewater treatment. Sustainable technology ensures a pollution-free society, compliance with environmental norms, and creation of wealth from waste.

1.4.1.6 Standard Operating Procedures

Standard operating procedures (SOPs) of wastewater treatment plants must be documented and available to operators for reference. It is important for operators to know their daily, weekly, and monthly responsibilities. Operators are a key resource in the wastewater treatment plant. Operators are responsible for managing pumps, probes, and filtration equipment, general housekeeping, testing alarms, and any other tasks to keep a safe and orderly facility. If new technologies are added to the system, operators must be trained to operate these.

1.5 Embedding Sustainability into Wastewater Treatment

Embedding sustainability into wastewater treatment provides the best opportunity for industries to drive smarter innovation and efficient wastewater treatment. To analyze the full scope of embedding sustainability into wastewater treatment we can use a lifecycle cost analysis tool. To reach a final decision, the different indicators should be normalized and weighted to integrate them into a single final objective, which makes the search for a sustainable solution a multi-objective optimization problem. Important objectives in selecting sustainable wastewater treatment technologies are as follows:

- Minimize use of resources such as water, energy, chemicals, and space.
- Minimize treatment costs.
- Minimize production of harmful waste products.
- Minimize use of manpower.
- Maximize the treatment efficiency.
- Maximize social-cultural embedding through acceptance, participation, and stimulation of sustainable behavior.

Due to the complexity and the dynamic understanding of today's problems, there is a risk of introducing new problems when implementing technical solutions. To ensure that solutions have a positive overall impact on society, one needs to be clear about lifecycle cost assessment.

In order to develop sustainable wastewater treatment, we need to evaluate wastewater treatment systems in a broad sense. Economic aspects, treatment performance, carbon emissions, recycling, and social issues are important when evaluating the sustainability of a wastewater treatment system and selecting an appropriate system for a given condition. Selection of a wastewater treatment scheme requires a multidisciplinary approach in which engineers and technocrats discuss with economists, biologists, health officials, and the public.

1.5.1 Optimizing the Operating Cost of Wastewater Treatment Plants

Under sustainability, optimizing the operating cost and reducing the environmental footprint of a wastewater treatment plant are very important. Here, one case study of the wastewater treatment cost of a chemical industry is presented to understand the actual cost associated with wastewater treatment inside a large chemical manufacturing plant (see Table 1.1). Based on actual data received from the wastewater treatment plants of various chemical industries, the author of this book summarizes the average cost of wastewater treatment within chemical and agrochemical manufacturing plants. This operating cost is for a biological wastewater treatment plant to treat effluent having an inlet COD of 5000–8000 ppm and treated outlet COD <250 ppm (see Figure 1.6).

Table 1.1 Average cost of wastewater treatment plants in chemical industries.

Cost monitoring parameters	Average cost (USD/m^3)
Power cost	1
Chemical cost	1.5
Sludge disposal cost	1
Treated effluent disposal cost	0.5
Manpower cost	1
Total cost	**5**

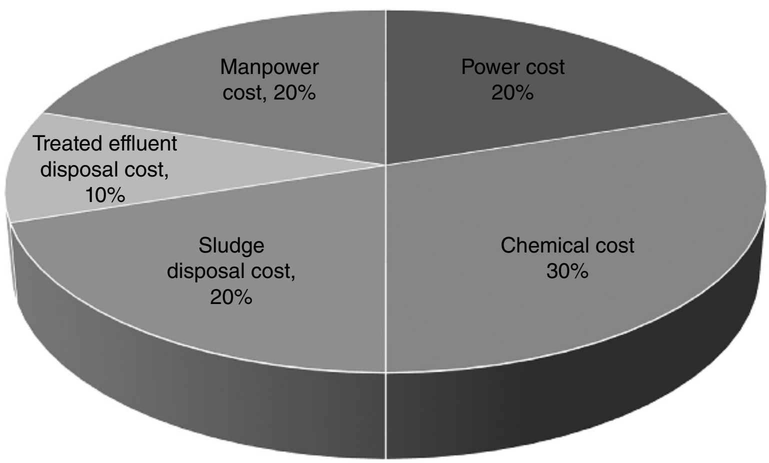

Figure 1.6 Operating cost composition of chemical industry wastewater treatment plants.

With the use of sustainable wastewater treatment technologies, we may further reduce power consumption, chemical consumption, sludge generation, and involvement of manpower in wastewater treatment plants.

1.5.2 New Sustainable Wastewater Treatment Technologies

Use of sustainable wastewater treatment technologies is a key factor in embedding sustainability into wastewater treatment. Sustainable wastewater treatment systems depend on a number of factors including minimal use of resources such as water, energy, chemicals, and space; minimum treatment costs; minimum production of harmful waste products; minimum use of manpower; maximum treatment efficiency; and maximum social-cultural embedding through acceptance, participation, and stimulation of sustainable behavior. Some of these new sustainable wastewater treatment technologies are now discussed.

1.5.2.1 Forward Osmosis

FO is a membrane-based wastewater treatment technology utilizing drawdown solution to treat high TDS (<100 000 ppm) and moderate COD (<20 000 ppm). FO is a natural process and an integral part of the survival of flora and fauna on this planet. In general, the FO process is governed by differences in osmotic pressure, and the direction of water diffusion takes place from a lower concentration (the feed side) to a higher concentration (the draw side). The driving force for this separation is an osmotic pressure gradient which is generated by a draw solution of high concentration to induce a net flow of water through the membrane into the draw solution, thus effectively separating the feed water from its solute. As osmosis is a natural phenomenon, it significantly requires less energy compared to the conventional reverse osmosis (RO) process. FO technology can be used for highly saline waters which are impossible to treat through conventional wastewater treatment processes (see Figure 5.6).

1.5.2.2 Scaleban

Scaleban is a unique and patented technology that helps industries achieve water conservation and zero liquid discharge (ZLD) by integrating process effluent and RO reject water having high TDS with existing cooling towers in place of freshwater. Scaleban uses a cooling tower as a natural evaporator without affecting the plant's performance in relation to hard water scaling, corrosion, and bio-fouling in the cooling tower circuit. With application of the Scaleban system, cooling towers can be operated at higher TDS; hence effluent treatment plant (ETP)-treated water/effluent can be used as the cooling tower makeup water, thus reducing raw water consumption without requiring any extra energy input for its operation (see Figure 1.7).

1.5.2.2.1 Advantages

- Reduced abstracted water demand in the cooling tower by utilizing treated wastewater.
- Much less capital and operational expenditure compared to conventional technologies to achieve ZLD.

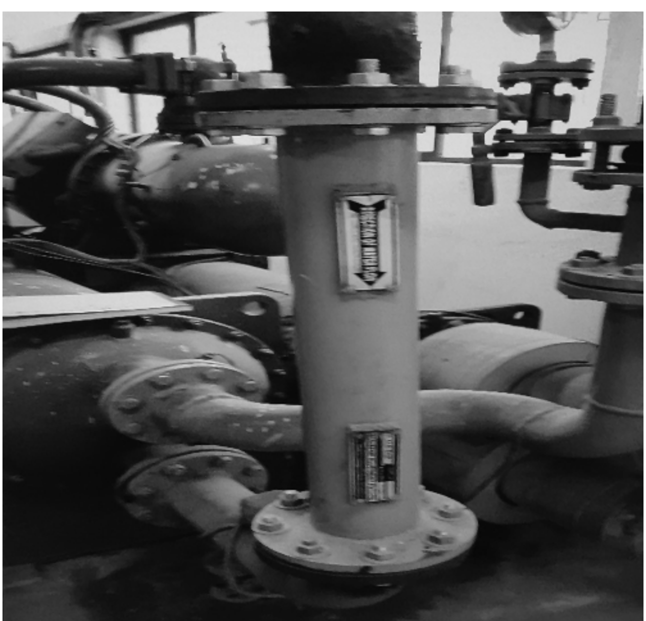

Figure 1.7 Scaleban equipment installed in a cooling tower.

Figure 1.8 Volute press equipment.

- Can handle higher COD and TDS water efficiently.
- Quick installation and commissioning without occupying any extra footprint.
- No major infrastructural changes required for installation.

1.5.2.3 Volute Press

A volute press is a multidisc sludge dewatering press that removes water and moisture from sludge on a continuous basis. It consists of two types of rings: a fixed ring and a moving ring. A screw tightens the rings and pressurizes the sludge. Gaps between the rings and the screw are designed to gradually get narrower toward the direction of the sludge cake outlet, and the inner pressure of the discs increases due to the volume compression effect, thickening and dewatering the sludge (see Figure 1.8).

1.5.2.3.1 Advantages

- Continuous and clean operation without regular manual intervention.
- Produces high-quality filtrate with much less total suspended solids (TSS) (i.e. high solid recovery).
- Extremely low power consumption – reduces power consumption up to 95%.
- Low noise and odor generation.
- Low wash water consumption.

1.5.2.4 Moving Bed Biofilm Reactor

The moving bed biofilm reactor (MBBR) system is an advanced activated sludge process whereby biological sludge is immobilized on plastic carriers having a very large internal surface area. The aeration system keeps the carriers with activated sludge in motion, thus providing a larger and wider contact between microorganisms and wastewater for efficient wastewater treatment (see Figures 3.13 and 1.9).

Figure 1.9 An MBBR plant.

1.5.2.4.1 Advantages

- Compact system with smaller area footprint compared to conventional activated sludge process.
- Higher food to microorganisms ration (F/M) loading with reduced retention time.
- Less biological sludge generation and no biomass recycling required.
- Faster installation and commissioning.
- Higher treatment efficiency.

1.5.2.5 Dissolved Air Floatation

Dissolved air floatation (DAF) technology is a modern version of conventional primary effluent treatment, where suspended solids are removed by dissolving atmospheric air in wastewater under pressure and then releasing the air in a flotation tank basin. The released air forms tiny bubbles, causing the suspended matter to float on the surface, and in turn can be removed from wastewater using a skimming device (see Figure 3.6).

1.5.2.5.1 Advantages

- Very compact system which reduces the area footprint significantly.
- Quick installation and commissioning.
- Higher suspended solids removal efficiency with ability to handle bulking floating solids.
- Lower capital expenditures (CAPEX) and operating expenses (OPEX).

1.6 Sustainable Sources for Industrial Water

Industrial water scarcity is one of the major impacts on businesses worldwide, leading to higher operating costs and difficulty in staying competitive. For industries, day by day controlling costs is difficult and this worsens when the price of water increases exponentially to the point where profit margins shrink precariously. This causes industries to regard water access as a competitive advantage and to adopt sustainable sources for industrial water. In the following sections, the various sources of industrial water along with approximate costs are summarized.

1.6.1 ZLD Water

ZLD water is generated inside industrial manufacturing plants by adopting ZLD treatment methods. Industry uses a number of technologies and various stages of wastewater treatment to get ZLD water. The approximate cost of ZLD water is in the range of USD 10–17/m^3 water produced. ZLD water not only is costly but also generates huge amounts of carbon and hazardous solid waste. Due to the higher cost and higher environmental footprint, ZLD water is not a sustainable source for industrial water.

1.6.2 Desalinated Water

Desalinated water is generated by desalination of seawater by adopting RO treatment methods. Industry uses various kinds of membrane to produce desalinated water. The approximate cost of desalinated water is in the range of USD 0.7–1/m^3 water produced. In coastal areas, desalinated water seems to be a sustainable source for industrial water.

1.6.3 Sewage Water

Sewage water is generated from municipal sewage treatment plants by treating domestic sewage. This treated domestic sewage will be further treated by industries as per requirement . Sewage generation is increasing rapidly on a global basis, and in the absence of adequate infrastructure for collection and treatment, the already depleting freshwater reservoirs are being polluted. In the present global water scarcity, *sewage wastewater is the new black gold on the planet Earth*. Various decentralized sewage treatment facilities are being set up for recycling and reuse of wastewater. Advanced treatment technologies are being adopted for sewage treatment. Globally, there is increasing focus on adding treatment capacity, improving collection efficiency, and automating operations for wastewater. New public–private partnership models and long-term operations and maintenance contracts are being introduced to benefit wastewater treatment plants. These measures will improve wastewater management and generate social, environmental, and economic benefits, and are essential to achieving Agenda 2030 SDGs.

The approximate cost of sewage water is in the range of USD 0.4–0.5/m^3 water produced. In areas where a sufficient amount of treated municipal sewage is available for industrial use, sewage water seems to be a sustainable and economical source for industrial water. By using sewage water in industrial manufacturing, we can also prevent water pollution.

1.6.4 Rainwater

During rainy seasons we get huge amounts of rainwater. We need to collect, store, filter, and reuse rainwater for manufacturing processes. Industrial rainwater is becoming increasingly important for commercial entities to reduce their environmental impact across their operations. Industrial rainwater harvesting is an extremely cost-effective method of achieving this goal, with the added benefit of reducing water consumption and bills. Industrial rainwater harvesting systems are easy to install and maintain, whilst providing

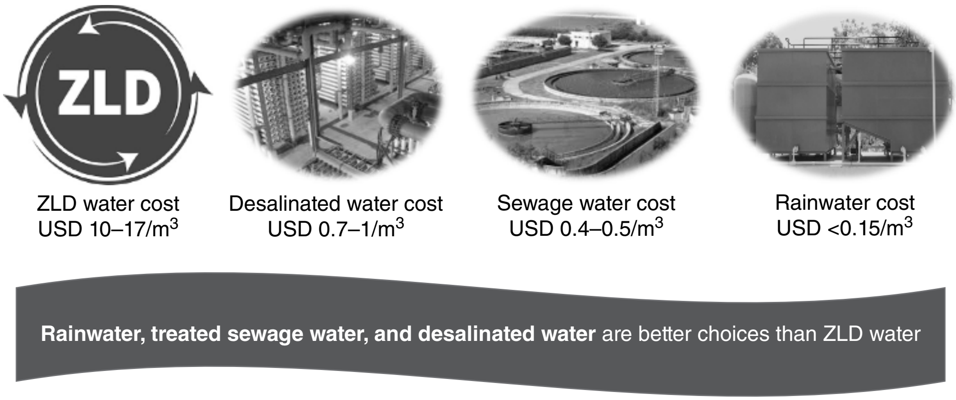

Figure 1.10 Alternative sources for industrial water.

cost-effective savings on water consumption; resulting in reduced water bills. The approximate cost of rainwater harvesting is less than USD 0.15/m^3 water produced. In areas where a sufficient amount of rainfall is available, rainwater is thus the better and sustainable choice of all available water options (see Figure 1.10).

1.7 Deep Sea Discharge as an Alternative to Minimize Human and Environmental Health Risks

Deep sea discharge of treated wastewater can be an effective, reliable, and economical solution to wastewater disposal that has minimal environmental impacts and avoids water pollution problems in coastal regions. The marine environment has a high capacity for dispersion and decay of organic matter. This capacity lies in the available energy in the marine environment due to the action of ocean currents on wastewater dispersion, the availability of dissolved oxygen, and due to it being a hostile environment to the survival of microorganisms.

The National Research Council of the US National Academy [4] specifically recommended against a "one size fits all" approach to arbitrary specification of treatment levels, stating:

> Coastal wastewater and stormwater management strategies should be tailored to the characteristics, values, and uses of the particular receiving environment based on a determination of what combination of control measures can effectively achieve water and sediment quality objectives.
>
> Sydney's deepwater ocean outfalls have delivered high-quality outcomes for the environment and the community [5]. Beaches and harbors are cleaner and the marine environment is healthy.

Since the deepwater ocean outfalls opened in 2004,

- Swimming conditions have significantly improved.
- Beach grease has been eliminated.
- There has been no detectable negative effect on marine ecology or sediments.
- Effluent discharged has consistently been shown to be non-toxic at its diluted state.

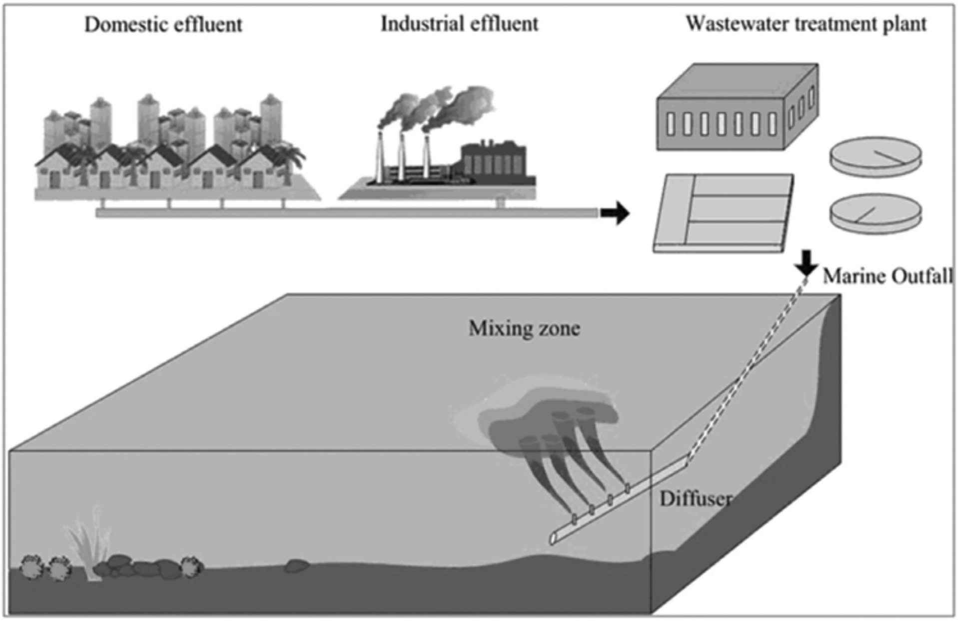

Figure 1.11 A deep sea discharge wastewater disposal system.

A typical deep sea discharge system for treated wastewater disposal is shown in Figure 1.11. It usually consists of a wastewater collection pipeline, combined wastewater treatment plant, and discharge structure – the deep sea discharge outfall.

Deep sea discharge outfalls release treated wastewater 2–10 km off the coast, where it mixes with seawater with the help of diffusers. The primary treated effluent is conveyed through tunnels under the ocean floor and is released through a series of diffusers. These diffusers release the effluent in fine jet streams, so it mixes immediately with seawater and disperses into the strong sea current. Because it is less dense than the salty seawater, the effluent moves upward and outward into the current as it disperses into an area called the mixing zone. At the same time, the current continues to move it away from the coastline. Natural processes eventually break down the effluent components, which are by now very highly diluted.

1.7.1 Mixing Zone

The mixing zone is very important for the dilution of wastewater in the sea. In the United States, the Environmental Protection Agency (US-EPA) regulations for toxics [6] define a mixing zone as:

An area where an effluent discharge undergoes initial dilution and is extended to cover the secondary mixing in the ambient water body. A mixing zone is an allocated impact zone where water quality criteria can be exceeded as long as acutely toxic conditions are prevented.

1.7.2 Deep Sea Discharge Outfalls

The major deep sea discharge outfalls for treated wastewater are summarized in Table 1.2.

Table 1.2 Deep sea discharge outfalls for treated wastewater discharge.

Location	Country	Distance from shore (km)
Honolulu (Honouliuli WWTP)	USA	2.67
Southern California Bight (Point Loma WWTP, San Diego)	USA	7.24
Santa Monica (Hyperion Water Reclamation Plant)	USA	8.1
Boston (Deer Island WWTP)	USA	15
Anglesea, Victoria (Barwon Water)	Australia	0.7
Geelong, Victoria (Black Rock Water Reclamation Point outfall)	Australia	1.2
Sydney (Malabar Island)	Australia	2.6
Cape Town (Green Point outfall)	South Africa	1.6
Cape Town (Camps Bay outfall)	South Africa	1.4
Cape Town (Hout Bay outfall)	South Africa	2.1
Ankleshwar, Gujarat (NCTL)	India	9.5
Mumbai (government sewage treatment plant, Bandra Reclamation)	India	3
Ipanema Beach, Rio de Janeiro	Brazil	4.3

NCTL, Narmada Clean Tech Ltd; WWTP, waste water treatment plant.

1.7.3 Wastewater Discharge Norms for Deep Sea Discharge Outfalls

The US-EPA has declared wastewater discharge norms for deep sea discharge outfalls (navigable water) based on effluent limitations guidelines representing the degree of effluent reduction attainable by application of the best practicable control technology currently available. India has declared general norms for wastewater discharge applicable for all types of discharge. These norms are summarized in Table 1.3.

Table 1.3 India vs US-EPA norms for deep sea discharges for pesticide and pharmaceutical industries.

Parameters	Pesticide industries effluent discharge[a] standards			Pharmaceutical industries effluent discharge standards	
	India[b]	US-EPA[c]		India[b]	US-EPA[d]
pH	6.0–9.0	6.0–9.0	6.0–9.0	6.0–9.0	6.0–9.0
COD	250 ppm	13 kg/ton production	4333 ppm	250 ppm	1675 ppm
BOD	100 ppm	7.4 kg/ton production	2466 ppm	100 ppm	267 ppm
TSS	100 ppm	6.1 kg/ton production	2033 ppm	100 ppm	472 ppm
Ammoniacal nitrogen	50 ppm	No limit	No limit	50 ppm	No limit
Oil and grease	10 ppm	NA	NA	10 ppm	NA

[a] For pesticide industries, average effluent discharge of 3 m^3/ton of production is assumed.
[b] Indian Central Pollution Control Board (CPCB) standards: http://cpcb.nic.in/displaypdf.php?id=sw5kdxn0cnktu3bly2lmawmtu3rhbmrhcmrzl0vmzmx1zw50lzqznc0xlnbkzg.
[c] US-EPACFRPart455Pesticideindustryeffluentstandard:https://www.epa.gov/eg/pesticide-chemicals-effluent-guidelines.
[d] Pharma US-EPA: https://www.epa.gov/sites/production/files/2015-10/documents/pharmaceutical-permit-guidance_2006.pdf.

1.8 Environmental Rule of Law

To achieve sustainable development, an environmental rule of law is a must. Environmental rule of law ensures a fair society, living within environmental limits, and creating a sustainable future for all. It is also a barometer for the health of government institutions that avre held accountable by an informed and engaged public.

Environmental laws have grown dramatically since the early 1990s, as countries have come to understand the vital links between the environment, economic growth, public health, social cohesion, and security [7]. As of 2017, 176 countries have environmental framework laws; 150 countries have enshrined environmental protection or the right to a healthy environment in their constitutions; and 164 countries have created cabinet-level bodies responsible for environmental protection. These and other environmental laws, rights, and institutions have helped to slow – and in some cases to reverse – environmental degradation and to achieve the public health, economic, social, and human rights benefits that accompany environmental protection.

1.8.1 The Polluter Pays Principle

The "polluter pays" principle is the commonly accepted practice that those who produce pollution should bear the costs of managing it to prevent damage to human health and/or the environment. For instance, a factory that produces a potentially poisonous substance as a by-product of its activities is usually held responsible for its safe disposal. The polluter pays principle is part of a set of broader principles to guide sustainable development worldwide known as the 1992 Rio Declaration [8]. Principle 16 states:

> National authorities should endeavour to promote the internalization of environmental costs and the use of economic instruments, taking into account the approach that the polluter should, in principle, bear the cost of pollution, with due regard to the public interest and without distorting international trade and investment.

1.9 Trends in Wastewater Treatment Technology

In the past, industries preferred the conventional design of wastewater treatment to meet statutory norms, but the current trend is toward modular design of wastewater treatment to meet the recycling norms; in future, the trend will be toward extreme modular design of wastewater treatment, fully equipped with smart technology. Figure 1.12 shows the trends in industries.

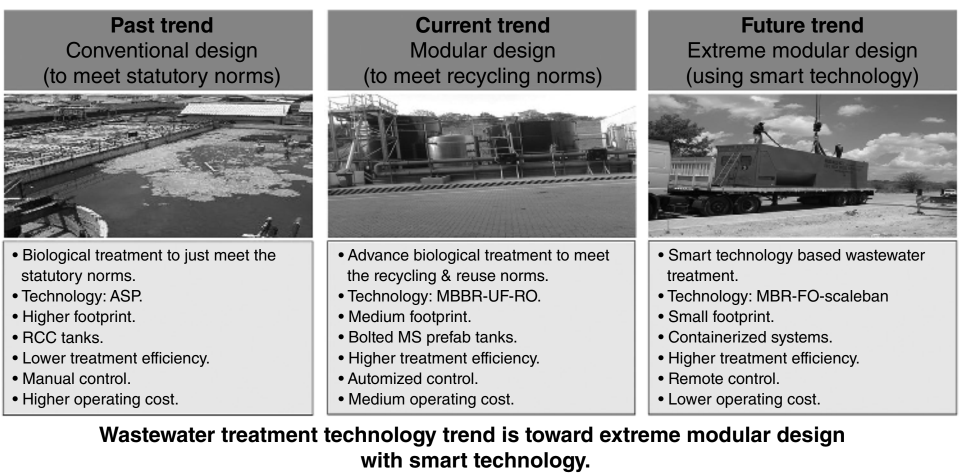

Figure 1.12 Wastewater treatment technology trends in industries.

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