WATER POLLUTION MANAGEMENT: AN IWRM APPROACH TO IMPROVING WATER QUALITY

TRAINING MANUAL

Companion facilitator guide

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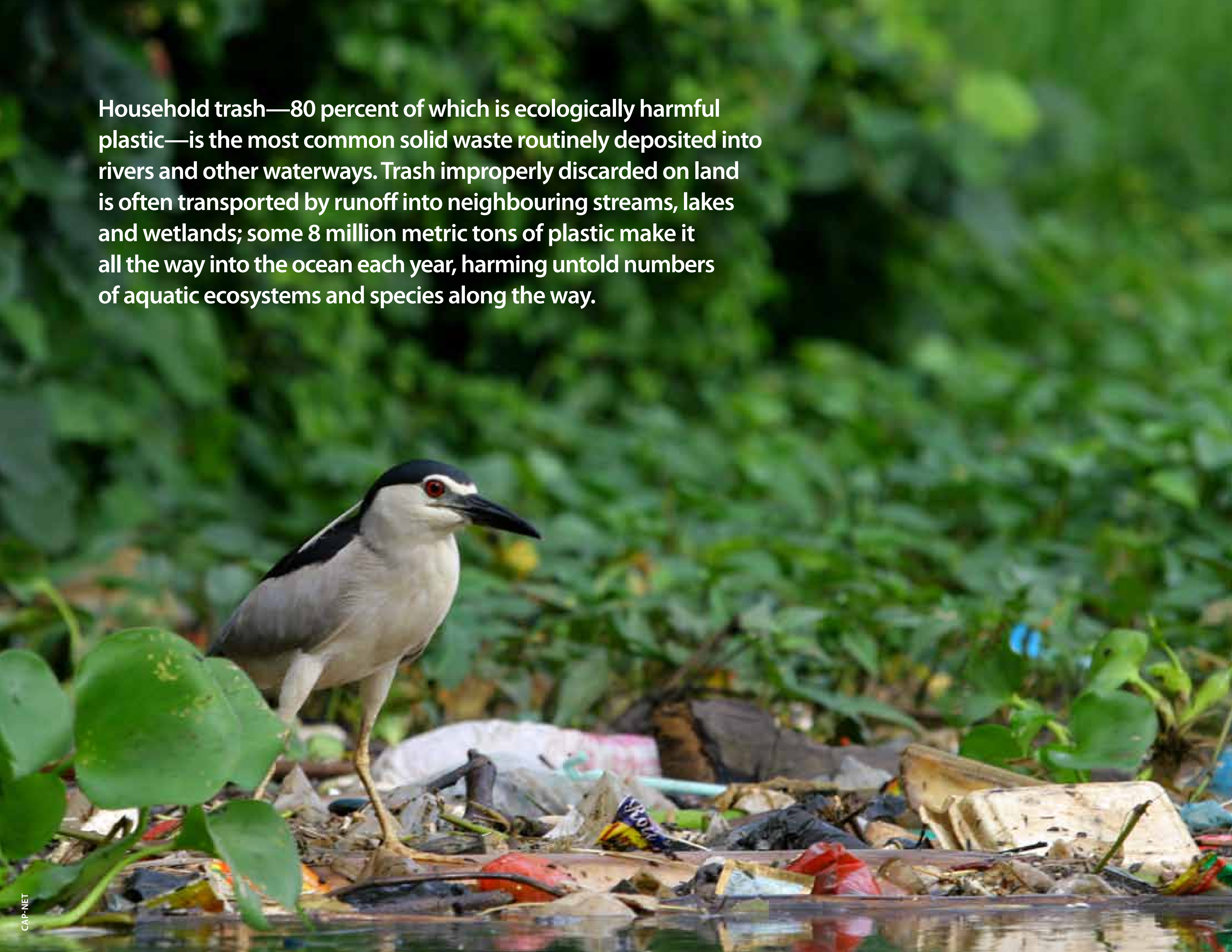
WATER POLLUTION MANAGEMENT

AN IWRM APPROACH TO IMPROVING WATER QUALITY

TRAINING MANUAL

Household trash—80 percent of which is ecologically harmful plastic—is the most common solid waste routinely deposited into rivers and other waterways. Trash improperly discarded on land is often transported by runoff into neighbouring streams, lakes and wetlands; some 8 million metric tons of plastic make it all the way into the ocean each year, harming untold numbers of aquatic ecosystems and species along the way.



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Foreword

Access to clean and risk-free water in sufficient quantities is a prerequisite for and an indicator of human well-being. Although water pollution is among the biggest human health risks, the continuing deterioration of water quality remains a major global threat. Water pollution also threatens the global ecosystem with potentially irreversible damage, exacerbating the environmental challenges of future generations.

As countries struggle to find solutions for water pollution prevention and water quality management, Cap-Net UNDP has taken steps towards consolidating knowledge on integrated management approaches. Although there is an abundance of technical knowledge on reducing point source pollution with centralized wastewater collection and treatment systems, non-point pollution presents an intractable problem as contaminated streams flow through urban and rural environments and the productive lands that support communities. Further, the bulk of wastewater collected worldwide remains untreated, and the pollution loads exerted on finite freshwater resources are immense and growing.

Water pollution is no longer only a technical problem, but also a management challenge. Both require knowledge to formulate solutions for planning and implementation of pollution prevention and management. The training material presented here endeavours to improve

The bulk of wastewater collected worldwide remains untreated, and the pollution loads exerted on finite freshwater resources are immense and growing.

practitioners' understanding of water pollution drivers, stakeholder involvement, and strategic planning for pollution prevention and management. The three pillars of integrated water resources management—social equity, environmental sustainability and economic efficiency—can contribute to managing pollution and eventually achieving an increase in people's well-being while protecting the environment. Areas covered in this training manual include: adapting and using economic and financial tools; improving the enabling environment through policy advocacy and institutional capacity-building; water quality monitoring; and knowledge and information management. The content is the product of extensive consultations among water experts, managers and other stakeholders. While this training package is organized in modules that provide session outlines to help effectively deliver the content, trainers can adapt material to the local context. Cap-Net hopes that this information will be useful in bridging knowledge gaps at the ground level.

Themba Gumbo
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COURSE OBJECTIVES

This training manual aims to build the capacity of water managers in particular, but also that of trainers, academics, government officials in relevant sectors, and representatives of non-governmental and administrative bodies that have a stake in development planning and can influence policy.

The training course based on this material aims to enable participants to:

- **Identify different actors and drivers of water pollution;**
- **Understand relationships among water pollution, ecosystem health and human well-being;**
- **Examine existing policies and the legislative and institutional structures related to water pollution prevention and quality management;**
- **Apply water quality guidelines and standards; and**
- **Facilitate strategic planning and financing for water pollution prevention and quality management.**


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Overview

Water pollution is an issue of global concern, as many countries are experiencing deteriorating water quality combined with growing demand. Pollution leads to economic water scarcity, as available water requires purification and infrastructure investment, which burden developing countries. This situation has led to countries agreeing on a target to halve the proportion of untreated wastewater, substantially increasing recycling and safe reuse globally by 2030. This target is an integral part of Sustainable Development Goal 6 on Water and Sanitation, which includes a range of inter-related targets and indicators that emphasise the need for a holistic water management approach. This training manual highlights the key water pollution issues and stakeholders, pollution prevention and control measures, integrated water resources management principles that can help mitigate pollution's impact on human health and the environment, and policy instruments that enable coordinated action.

A considerable further effort must be made at all stakeholder levels and sectors to make progress on preventing pollution and restoring ecological balance. Such objectives requires relevant national policies and legislation, supported by comprehensive water quality monitoring and regulation enforcement. Because agricultural and industrial—or point source—pollution instances are more visible than non-point source pollution, actual pollution levels remain underreported, resulting in the lack of relevant remedies. Addressing water pollution from an interdisciplinary perspective would yield more integrated solutions and provide a roadmap for collaborative action.

A considerable further effort must be made at all stakeholder levels and sectors to make progress on preventing pollution and restoring ecological balance. Such objectives requires relevant national policies and legislation, supported by comprehensive water quality monitoring and regulation enforcement.

Water pollution management[1] requires the participation of all stakeholders—polluters, victims, water managers and policymakers—under an integrated water resources management (IWRM) approach, as detailed in this training manual. The training course consists of 11 modules. Content is organized within three sections: water pollution issues, impacts and integrated management, the enabling environment, and water pollution management interventions. The training manual considers the interlinkages among different sectors and issues related to water pollution and provides guidance on identifying interdisciplinary challenges, bringing them into policy discourse, and planning for pollution prevention and management.

The accompanying facilitators guide includes a description of each module and session, together with different exercises that can be practiced in training, guiding the trainer to lead participants for effective learning in each and every module.

Module 1 aims to ensure practitioner understanding of the global scale and nature of water pollution within the Driving forces, Pressures, States, Impacts and Responses (DPSIR) framework. Pollution of surface and groundwater distresses the ecosystem, reduces water usability, and increases disease occurrence and spread.

Module 2 provides a comprehensive overview of the interrelationships among water, ecosystems and human well-being. The module discusses the impacts of water pollution on ecosystem health and, consequently, on human health, and the important role of natural ecosystems in water pollution management.

Module 3 presents pollution control as an essential part of IWRM, emphasizing the need for all stakeholders' participation. This module examines water pollution and related issues from an IWRM viewpoint, demonstrating that an enabling environment, institutional arrangements and management instruments are the prerequisites for successful pollution remedies.

1 'Water pollution management' denotes the process of addressing water pollution as a whole, from controlling water pollution to applying management instruments to reduce, treat and prevent water pollution.

Module 4 elaborates the key international principles and guidelines for controlling water pollution, details policies and legislative arrangements, and defines an appropriate institutional and management framework. As many sectors play a role in and are affected by water pollution, the integrated approach that defines IWRM is directly relevant and beneficial.

Module 5 presents a strategic framework for water pollution control and management, including guiding principles, commonly used instruments, and developing a pollution prevention and management action plan.

Module 6 focuses on water quality management, providing an overview of quality standards, quality assessment, risk classification and identification, and examples of innovative and proactive measures for improving or maintaining water quality.

Water pollution management requires the participation of all stakeholders—polluters, victims, water managers and policymakers—under an integrated water resources management (IWRM) approach, as detailed in this training manual.

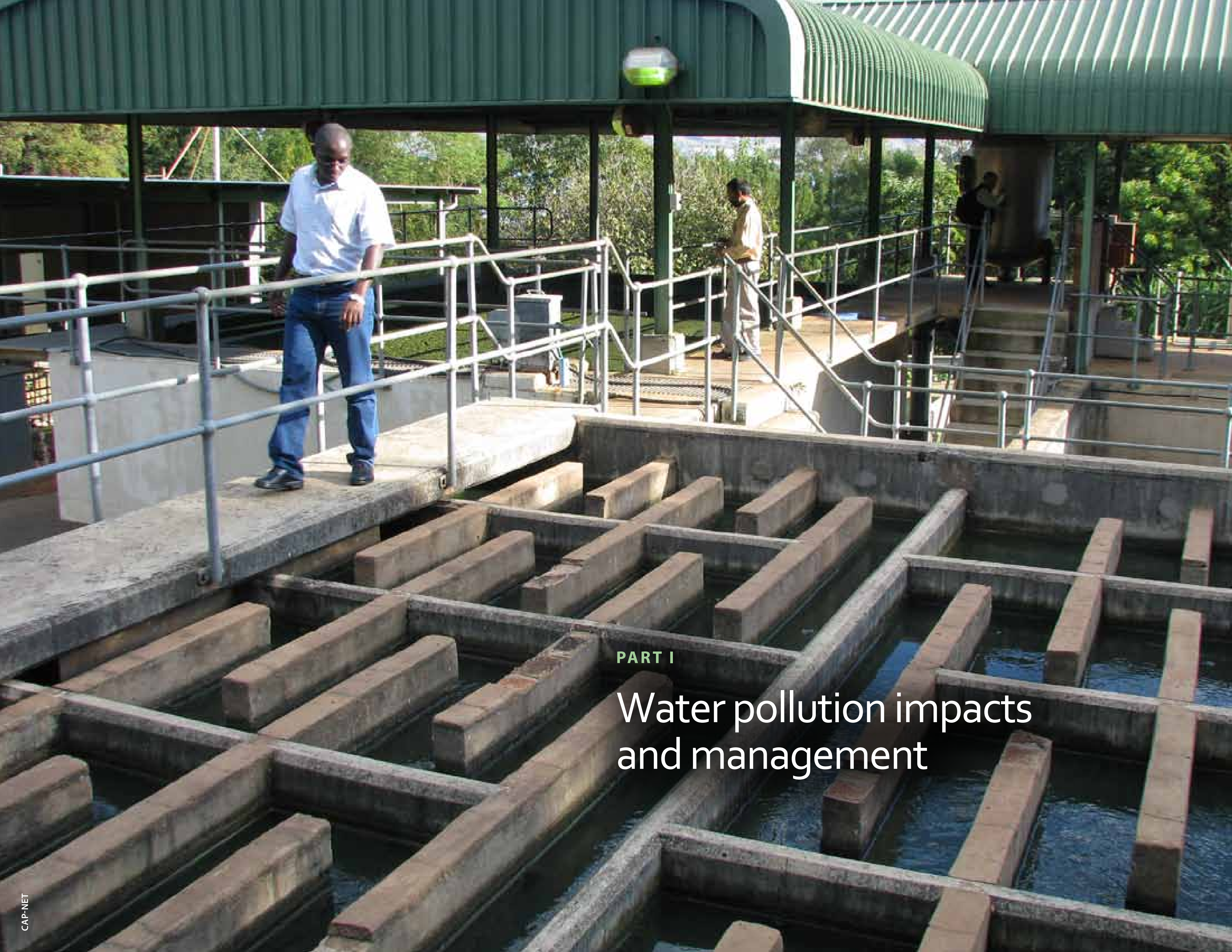
Module 7 builds understanding of economic and financial instruments for addressing water quality and pollution. Fiscal means such as public finance, charges and taxes for controlling pollution are important components of water management, ensuring its sustainability.

Module 8 discusses stakeholder engagement, from identifying stakeholders, categorizing them and understanding how to best reach each group—to enhancing participation and ensuring efficient coordination in water pollution prevention.

Module 9 recommends water pollution licensing as a means of controlling wastewater discharge and ensuring water resources meet quality standards. Licensing can address both point and non-point source pollution.

Module 10 emphasizes the importance of ongoing monitoring for water quality management. Setting up monitoring networks is important for upholding discharge regulations, conducting water quality tests and gathering data and information to measure the effectiveness of interventions and inform future decisions.

Module 11 addresses information management for catchments or specific concerned areas, including the methods for collecting, storing and managing information, and the types of information and data most useful for planning and monitoring.



PART I

Water pollution impacts and management

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LEARNING OBJECTIVES

In this module, participants will learn about:

- **Global scope of water pollution;**
- **Main driving forces of wastewater discharges and forecasted developments, including climate change;**
- **Main sources of water pollution; and**
- **Pollution impact on humans and the aquatic ecology.**

MODULE 1

Scope, drivers and impacts

Worldwide, there is clear evidence of an increasingly downward trend in water quantity and quality: drying rivers, aquifers and groundwater basins; bioaccumulation of agrochemicals and heavy metals in fish; algal blooms from high nutrient loads; and dam siltation and nutrient loss from river disturbances. Many of these impacts are caused by pollution from cities, industry and agriculture. Overexploitation and ecosystem degradation are caused by water users and polluters who seldom suffer direct consequences of their actions.

Clearly, considerably more dedicated effort is needed in water pollution prevention, if it is to achieve and sustain agreed water quality objectives for specific regions, countries and river basins, including both surface and groundwater bodies. Two distinct groups of actors, water resources managers/regulators and water users/polluters, need to cooperate to ensure that aquatic ecosystems survive and maintain productivity.

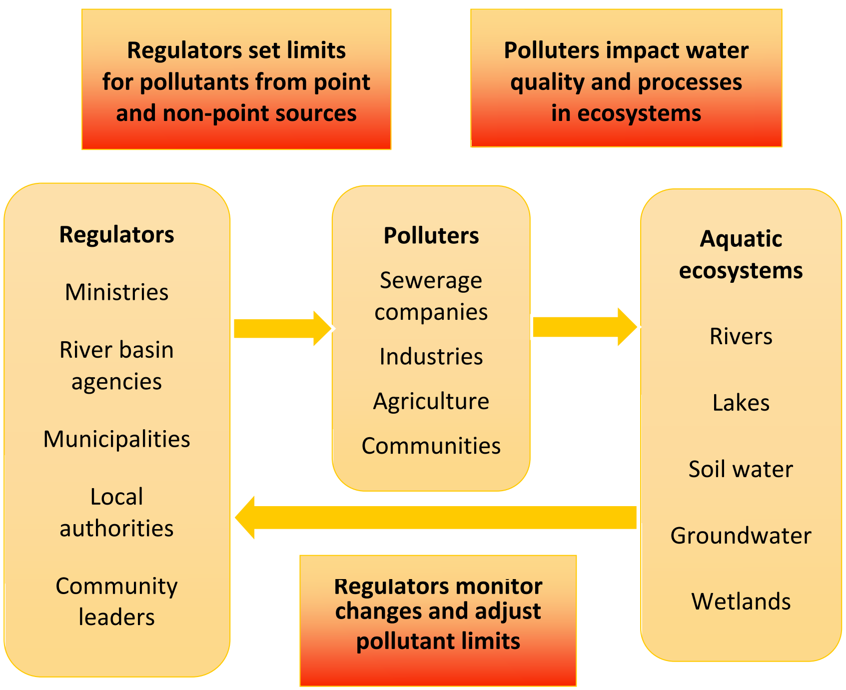
Minimizing the level of pollution and thus protecting the state of an ecosystem requires a firm regulator backed by clear policies and legislation, cooperation between the regulator and polluters, and a comprehensive monitoring and enforcement system. In addition, both regulators and polluters need to understand the integrated processes within aquatic ecosystems—all types of freshwater and coastal water environments—in water management planning by carefully considering their natural processes and carrying capacities of aquatic ecosystems. (See Figure 1.1.)

1.1 GLOBAL SCALE OF WATER POLLUTION

Pollution typically refers to chemicals or other substances in concentrations greater than would occur under natural conditions. Major water pollutants include microbes, nutrients, heavy metals, organic chemicals, oil and sediments; heat, which raises the temperature of the receiving water, can also be a pollutant. Pollutants are the central cause of water quality degradation around the world, as virtually all production activities generate pollutants as unwanted by-products.

More than three quarters (80 percent) of the wastewater from human settlements and industrial sources worldwide is discharged untreated directly into water bodies.[2] Experts believe that water pollution will continue to rise globally, as a result of economic development driven by urbanization, industries and intensive agriculture systems, unless substantial progress is made in regulation and enforcement. Many industries—including some that are known to be heavily polluting (e.g. leather tanneries, chemicals)—are moving operations from high-income countries to emerging economies, where they benefit from various incentives, a lower-cost workforce and, in some cases, less stringent environmental regulations. Because of inadequate monitoring systems, many countries lack information on pollution loads and water quality changes. As a result, the often serious impacts of polluting activities on human and ecosystem health remain unreported or underreported and, consequently, easily ignored or forgotten.

FIGURE 1.1 BROAD INTERACTIONS AMONG REGULATORS, POLLUTERS AND AQUATIC ECOSYSTEMS



2 UNEP and UN-HABITAT 2010.

BOX 1.1 GLOBAL FRESHWATER SUPPLY

- **Only 2.5 percent of all water on earth is freshwater; 97.5 percent is saltwater.**
- **Freshwater is largely inaccessible: 69 percent of global freshwater is frozen in Antarctica and Greenland icecaps, 30 percent is groundwater or soil moisture, and approximately 0.26 percent of freshwater exist in the lakes and rivers.**
- **Only less than 1 percent of all freshwater, which accounts for 0.01 percent of all water on earth, is the usable portion of water resources available for withdrawal and human use.**
- **Withdrawn freshwater is used for:**
  - **Agriculture (70 percent), with drainage water returned to nature with pollutants such as high salt content, high content of fertilizer and presence of toxic chemical pesticides;**
  - **Industrial purposes (22 percent), with wastewater returned to nature containing, for example, high heavy metal content; and**
  - **Urban and rural water supply (8 percent), with high organic content exemplifying wastewater quality issues.**

Sources: UNEP 2012, WBCSD 2005.

Water pollution has the grave effect of reducing the already small freshwater resources, making available water unsuitable for many purposes without substantial treatment—an economically and technologically unfeasible endeavour in many countries.

In 2015, an estimated 1.8 billion are living in countries or regions with absolute water scarcity, and two thirds of the world population live under water stress conditions.[3] Severe water pollution can lead to a water stress situation, as freshwater sources become unusable without incurring high cleaning costs. Given globally recognized water scarcity, using the world's accessible freshwater in a sustainable manner becomes critically important.

Freshwater uses are numerous and include water for people, water for food, water for nature, water for industry and others. Each use has different water quality requirements, and only where small amounts of water can produce high economic value. Treatment to remove pollutants and foreign substances is considered a viable option, without measures to reduce pollution at the source.

3 UN Water 2013.

Wastewater-related pollution has significant negative impacts on irrigation and ecosystems, the biggest water users. Many domestic and industrial water users can procure high-quality water in the relatively small amounts needed; however, pollution has a very real negative impact on vulnerable communities—the poor and marginalized groups already disadvantaged by lack of access to effective water services.

DISCUSSION QUESTIONS

How does **this compare with the situation in your country? Are there pollution management systems and how do they work? Who are the victims of water pollution?**

1.2 WATER POLLUTION DRIVERS

The principal driving forces are population growth, industrial and agricultural development, deforestation, and natural changes, such as those in meteorological conditions and ecosystem composition (e.g. aquatic vegetation and fish species). Environmental pressures resulting from these driving forces are point-source pollution loads (e.g. domestic and industrial) and non-point pollution (e.g. land runoff and leaching of nutrients).

The principal driving forces are population growth, industrial and agricultural development, deforestation, and natural changes, such as those in meteorological conditions and ecosystem composition.

In turn, such pressures alter ecosystems by increasing nutrient concentrations, algal growth and eutrophication, lowering of oxygen content, hydrogen sulphide formation and fish mortality. Alongside continuously decreasing freshwater usability and growing incidence of water-related and insect-borne diseases, the inevitable long-term impacts of water pollution are ecosystem degradation, decreased fish resources, and loss of amenity values and biodiversity.

The driving forces and resulting impacts are best examined under the Driving forces, Pressures, States, Impacts and Responses (DPSIR) framework (see Section 5.1.2).

BOX 1.2 THE WATER-POOR ARE EXTREMELY VULNERABLE TO THE IMPACTS OF WATER POLLUTION

The water-poor include:

- **Those whose livelihood is persistently threatened by water pollution, severe drought or flood;**
- **Those whose livelihood depends on cultivation of food or gathering of natural products, and whose water source is not dependable or sufficient;**
- **Those whose water supply is contaminated bacteriologically or chemically, and who cannot afford to use or have no access to an alternative source;**
- **Women and girls who spend hours a day to collect safe water, and whose security, education, productivity, and nutritional status is thereby put at risk; and**
- **Those living in areas with high incidence of water-associated disease (e.g. bilharzia, guinea-worm, malaria, trachoma, cholera, typhoid) without means of protection.**

1.2.1 Population increase

Global populations are increasing at an average annual global growth rate of 1.1 percent, and world population is projected to rise from 7.3 billion in 2015 to 9.6 billion in 2050.[4] By 2050, global water demand is expected to increase by 55 percent, mainly due to growing demands from manufacturing, thermal electricity generation and domestic use. As population increases so does production of wastewater and the number of people vulnerable to the impacts of severe pollution. Almost 1.1 billion people currently lack access to safe drinking water and an estimated 2.4 billion people lack access to basic sanitation. The poorest and most vulnerable groups are those most in danger of suffering from the impacts of the water pollution (see Box 1.2).

1.2.2 Economic growth

Gross domestic product (GDP) growth reached 3.1 percent in 2015 and is projected at 3.4 percent in 2016 and 3.6 percent in 2017; emerging economies are projected to have higher GDP gains.[5] Production is increasing and each person consumes increasingly more water and goods associated with wastewater generation and pollution. Likewise, higher living standards and richer foods lead to more biological waste (excreta) produced per person on average.

1.2.3 Climate change

Changes to global climate patterns are a reality that impacts our daily lives and affects water availability. According to United States National Aeronautics and Space Administration (NASA), Earth's average temperature has risen by 1.5°F over the past century and is projected to rise by another 0.5–8.6°F over the next 100 years. Should such forecasts become a reality due to poor mitigation, huge changes will occur within water resources and aquatic ecosystems—among others.

4 UNDP 2015.
5 IMF 2016.

Increased water temperature can adversely affect different species inhabiting the ecosystem, depending on sensitivity. The health of a body of water, such as a river, depends on its ability to effectively self-purify through biodegradation, which is hindered when water warms and consequently loses its ability to hold the dissolved oxygen that facilitates the breakdown of pollutants.

1.2.4 Urbanization

In 1950, a third of the world's population lived in cities; in 2000, nearly half were city dwellers; and by 2050, urbanites will account for 68 percent.[6] This rapid increase is expected mainly in developing countries.[7] Water consumption and wastewater generation per capita are higher in urban environments than in rural areas, leading to pollution growing along with cities.

BOX 1.3 SANITATION AND POLLUTION IMPACTS IN BIG CITIES

Big cities with poor sanitation infrastructure can easily be swamped by human waste. In Jakarta, Indonesia, with a population of 9.6 million people, less than 3 percent of the 1.3 million cubic metres of sewage generated each day reaches a treatment plant.

There are more than a million septic tanks in the city, but these are poorly maintained and have contaminated the groundwater with faecal coliform bacteria. Tanks are often illegally emptied, with untreated waste dumped into waterways.

Because 60 percent of Jakarta's residents are not connected to the municipal water grid and rely on wells, subsidence is a significant problem that exacerbates flooding. Jakarta's network of canals, originally built to control flooding, has been partially filled with silt and garbage. Consequently, heavy rain and high tides cause flooding, and stagnant stormwater and wastewater combine to create ideal conditions for the spread of water-related diseases such as dengue fever, diarrhoea and leptospirosis.

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6 UNDP 2015.
7 Ibid.

Growth is often unplanned, and attracting government and private investment to infrastructure development in areas that lack the economic clout of megacities is difficult.


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Nearly 40 percent of the world's urban expansion may be in slums, exacerbating economic disparities and unsanitary conditions.[8] The combination of such factors will continue to fuel pollution growth, further hindered by lack of planning and similarly nonexistent collection and treatment systems for both solid waste and wastewater.

Growth is often unplanned, and attracting government and private investment to infrastructure development in areas that lack the economic clout of megacities is difficult. In addition, almost 700 million urban slum dwellers lack adequate sanitation, which, along with the paucity of safe drinking water, raises the risk of communicable diseases such as cholera and diarrhoea, particularly among children.[9] Because these informal settlements lack land tenure, securing investment in the infrastructure needed to provide water and sanitation services is extremely difficult. This is aggravated by the cost of such infrastructure, which is non-affordable for the slum dwellers, who can only hope for cross-subsidies.

DISCUSSION QUESTIONS

Do you know what proportion of your city is serviced by a sewerage system? How does a sewerage system contribute to pollution control and management?

1.2.5 Industrial development

Lack of sewerage systems limits the opportunity for disposal of industrial waste, especially for small and medium sized industries. In many developing countries, more than 70 percent of industrial waste is dumped untreated into waters, polluting the otherwise usable water supply.[10] Industrial discharge can contain a wide range of contaminants and originate from

8 Ibid.
9 Ibid.
10 UNEP and UN-HABITAT 2010.


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a multitude of sources. Mining, pulp mills, tanneries, sugar refineries and pharmaceutical production companies are among the biggest generators of toxic industrial waste. In many instances, wastewater from industry not only drains directly into rivers and lakes, it also seeps into the ground, contaminating aquifers and wells. This pollution of water supply often goes undetected in developing countries, as monitoring is expensive and complex. Existing sewerage systems cannot cope with industrial waste (see Box 1.4).

Mining has traditionally been a major source of unregulated wastewater discharge in developing countries. Waste from mining operations can contain silt and rock particles and surfactants. Depending on the type of ore being mined, tailings can also contain heavy metals, including arsenic, copper, lead, mercury and zinc. The contaminants in mining waste may be carcinogenic or neurotoxic to people (e.g. lead and mercury) or extremely toxic to aquatic organisms (e.g. copper).

1.3 LINKS AMONG WATER POLLUTION, WASTEWATER AND FOOD PRODUCTION

Wastewater has long been used as a resource in agriculture. In addition to living pathogens such as bacteria, parasites and viruses, wastewater often contains pollutants that result from agricultural and mining practices.

Agriculture, primarily the cultivation of nitrogen-fixing crops and the manufacture of fertilizer, converts about 120 million tons of atmospheric nitrogen per year into nitrogen containing compounds.[11] Up to two-thirds of this nitrogen makes its way into rivers, lakes and the coastal zone. This addition of nitrogen exceeds all natural inputs to the nitrogen cycle.[12]

11 Rockström et al. 2009.
12 Ibid.

Phosphorus mining presents a similar situation: we mine approximately 20 million tons of phosphorus a year to be used mainly as fertilizer,[13] but almost half of it finds its way back into the ocean, rivers and lakes. This produces approximately eight times the natural input. Together, excess nitrogen and phosphorus are the cause of, for instance, toxic algal blooms and anaerobic conditions that impact both fish and human health.

Only 1 percent of the sprayed pesticides are effective; 99 percent of pesticides applied are released to non-target soils, water bodies and atmosphere, and finally absorbed by almost every organism, posing serious threat to aquatic ecosystems and people.

Globally, 4.6 million tons of chemical pesticides are annually sprayed into the environment.[14] There are currently about 500 pesticides with mass applications, of which organo-chlorined pesticides, some herbicides and the pesticides containing mercury, arsenic and lead are highly poisonous to the environment.[15] Only 1 percent of the sprayed pesticides are effective; 99 percent of pesticides applied are released to non-target soils, water bodies and atmosphere,[16] and finally absorbed by almost every organism, posing serious threat to aquatic ecosystems and people. North America accounts for 36 percent of world pesticide use.[17] With increased public concern about the health effects of pesticides and recognition of the special vulnerability of children and indigenous peoples living in the north, pesticide regulations in North America became more stringent during the 1990s. Based on information from the countries providing data on irrigated areas, it is estimated that more than 4–6 million hectares are irrigated with wastewater or polluted water, but a separate estimate indicates 20 million hectares globally—an area that comprises nearly 7 percent of the world's total irrigated land.[18] Though there is no confirmed figure on wastewater-irrigated land area, considerable farming population around the world use wastewater in agriculture, particularly in arid or semiarid regions and peri-urban areas where unpolluted water is a scarce resource. Contamination of natural water bodies can only be reduced with good care and treatment. Currently, an estimated 10 percent of the world's population relies on food grown with contaminated wastewater. Studies show that in Pakistan, about 26 percent of national vegetable production originates from urban

13 Ibid.
14 Zhang et al. 2011.
15 Ibid.
16 Ibid.
17 UNEP 2002.
18 IWMI and IDRC 2010.

and peri-urban agriculture irrigated with wastewater, while in Hanoi's peri-urban agriculture, diluted wastewater is used to grow 80 percent of the perishable foods sold in local markets.[19] Apart from the reported figures of wastewater-irrigated agriculture, irrigation wastewater is rich with pesticides and fertilizer-based substances, as discussed in many articles and papers around the world.

1.4 POLLUTION IMPACTS ON HUMAN HEALTH AND WELL-BEING

1.4.1 Infectious disease

UN PHOTO/SOPHIA PARIS

Estimates of the global burden of water-associated human diseases provide a simple index hiding a complex reality. The World Health Organization estimates that diarrhoeal diseases are the forth main cause of death among under-5-year-old children, accounting for 11 percent of the 6.4 million deaths.[20] Unsafe water supplies and inadequate levels of sanitation and hygiene increase the transmission of diarrhoeal diseases (including cholera), trachoma and hepatitis.

The burden of disease is about more than just mortality; it also takes into account the proportion of healthy life years lost (see Table 1.1). The disability-adjusted life year (DALY) is a time-based measure of the burden on community health that combines years of life lost to illness and premature mortality. Diarrhoeal diseases rank fifth, falling from second place in 2000, yet remaining among the major causes of child death.

19 Ibid.
20 WHO 2015.

TABLE 1.1 GLOBAL BURDEN OF DISEASE: DIARRHOEA COMPARED TO OTHER DISEASES (ALL AGE GROUPS, DALY IN MILLIONS)

DISEASE OR INJURY	2012		2000	
	DALYS	PERCENTAGE OF TOTAL	DALYS	PERCENTAGE OF TOTAL
Ischaemic heart disease	166	6.0	142	5.0
Lower respiratory infections	147	5.4	208	7.3
Stroke	141	5.2	125	4.4
Preterm birth complications	107	3.9	123	4.3
Diarrhoeal diseases	100	3.6	161	5.6

Source: DALY estimates 2000-2012. See http://www.who.int/healthinfo/global_burden_disease/estimates/en/index2.html

The World Health Organization estimates that diarrhoeal diseases are the forth main cause of death among under-5-year-old children, accounting for 11 percent of the 6.4 million deaths.

It is difficult to screen out which fraction of the disease burden can be attributed to lack of pollution control and management. Human diseases can pass through one of two transmission pathways: the faecal-oral pathway (i.e. disease-causing microbes originating from faecal contamination are ingested with contaminated water or food) or the ecosystem, where wastewater accumulates, providing a pathway for certain human diseases.

1.4.2 Non-communicable disease

It is even harder to document ill health related to exposure to toxic compounds, because of complexities of the exposure pathways and the long-term effects of low-dose exposure, not easily distinguished from the impacts of other concurrent hazards and risks. Pesticides and pesticide residues in agricultural run-off, heavy metals and toxic compounds in industrial waste, and a group of persistent organic pollutants are among those posing health hazards.


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1.4.3 Access to sanitation

The connection between wastewater and human health is linked with access to sanitation and solid and liquid waste disposal. Adequate sanitation creates a barrier between human excreta and drinking water. Control and elimination of faecal contamination of water is a key component of health risk management.

1.4.4 Solid waste

Disposal of solid waste into rivers and the unplanned dumping of solid waste that ends up in rivers via runoff have a significant impact on health of the ecosystem and downstream communities. Dumping sites located close to water bodies can result in the leaching of toxic compounds to groundwater and rivers, altering their biotic components. Therefore, solid waste management is also closely linked with water pollution control.

DISCUSSION QUESTION

Should polluters accept responsibility for the downstream impact on people's health?

1.5 POLLUTION IMPACT ON ECOSYSTEM FUNCTIONS


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The Millennium Ecosystem Assessment demonstrated how modifying landscapes to increase food production and allow development has resulted in adverse ecological changes to many ecosystems, with accompanying loss and degradation of ecosystem services.[21] Though synergistic and cumulative effects can make it difficult to attribute such losses to a single cause, they have harmful effects on livelihoods and economic production. Some ecosystems have already passed thresholds into regime shifts, with a collapse in ecosystem services, making the cost of restoration (if at all possible) very high.

In many instances, consumptive use and water diversion have severely degraded downstream wetlands and closed basins. Large-scale examples include the Aral Sea in Central Asia and Lake Chapala in Mexico, the world's largest shallow lake. Some of the largest rivers—such as the Colorado, Murray-Darling, Nile and Yellow—have become small streams close to their mouths, and flows are no longer sufficient to maintain aquatic ecosystem health. Water pollution is among the most direct drivers for depletion of eco-system services as it harm the soil, water and biota in various ways.[22] Pollution from point sources such as mining has shown devastating local and regional impacts on the biota of inland waters.

Water infrastructure development—including dams, irrigation schemes, urban water supply and sewerage extension, aquaculture and others—has major consequences for the key ecological components and processes of rivers, lakes, floodplains and groundwater-fed wetlands. During the last century, the number of such modifications increased tremendously. In 2000, there were more than 45,000 large dams in operation.[23] Demand for reservoirs of all sizes is expected to continue to grow, particularly in regions with high water demand and the need to cope with the increased variability accompanying climate change.[24]

21 WRI 2005.

22 Ibid.

23 The International Commission on Large Dams (ICOLD), established in 1928, defines a large dam as a dam with a height of 15 metres or more from the foundation. If dams are between 5 metres 15 metres high and have a reservoir volume of more than 3 million cubic metres, they are also classified as large dams (World Commission on Dams 2000).

24 WWAP 2009.

Some ecosystems disappear when rivers are regulated or impounded, because of the altered flow and new barriers to the movement of migratory species. Of the world's 292 largest river systems that accounted for 60 percent of the world's runoff in 2005, 105—or more than a third—were strongly affected by infrastructural elements, and 68 were moderately affected.[25] While the impacts are greater for aquatic ecosystems, terrestrial ecosystems such as forests and grasslands are also affected by infrastructure changes to the water bodies that support them.

It is important to note that water pollution impacts carry beyond its source locations and surrounding areas. As such, water pollution management requires a holistic approach to ecosystems and river basins. (See Module 3 for an in-depth discussion of environment and pollution.)

KEY MESSAGES

- **Water pollution is on the rise globally, driven by population growth, industrial and agricultural development and deforestation, and exacerbated by changes in ecosystem composition and natural conditions (e.g. climate change).**
- **More than 60 percent of the world's population will be urban by 2030, while many of today's cities lack effective wastewater infrastructure and have difficulty securing investment to address the problem.**
- **Industrial development presents an enormous challenge by introducing many different and often toxic effluent substances into water sources that end up feeding into the water supply.**
- **Roughly 70 percent of developing countries' industrial waste is dumped untreated into receiving waters.**
- **Agricultural use of fertilizers is a major source of toxic algal blooms and anaerobic conditions in rivers and lakes, while agrochemicals pose serious threats to human health and aquatic ecosystems.**
- **Water-related human diseases is caused by unsafe water, inadequate sanitation and poor hygiene, filling half of the world's hospital beds and accounting for approximately 3.7 percent of all deaths.**
- **The ecosystem services on which we all depend remain constrained by an incomplete understanding of the magnitude and impact of pollution.**

25 Ibid.

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LEARNING OBJECTIVES

In this module, participants will learn to:

- **Understand the interrelationships among water, ecosystems and human health;**
- **Understand and appreciate the multiple services provided by natural ecosystems, including water storage, supply and purification within a river basin;**
- **Identify the impacts of water pollution on ecosystem health and human well-being; and**
- **Utilize the ecosystem approach and integrated management in water pollution control in a river basin.**

MODULE 2

The role of ecosystem services

Water is a key abiotic component of ecosystems. Ecosystems modify the hydrological cycle and the chemical and physical characteristics of water. Sufficient quality and quantity of water and healthy ecosystems within a river basin form the basis for human well-being and sustainable development. The relationship between ecological and socio-economic systems (i.e. human well-being) is illustrated in Figure 2.1.

Healthy ecosystems possess full ecosystem functions. Ecosystem services are the direct and indirect ecosystem contributions to human well-being.[26] Several classifications of ecosystem services exist, including those presented by the Common International Classification of Ecosystem Services (CICES),[27] the Millennium Ecosystem Assessment[28] and TEEB[29] (see Table 2.1). Ecosystem services related to water pollution management are discussed in more detail in Section 2.2. It is critical to note that the utilization of these ecosystem services impact the ecosystems and that sustainable utilization relies on understanding and respecting the carrying/assimilative capacity, or tolerance limit, of the ecosystems.

26 TEEB 2010.
27 CICES 2013.
28 WRI 2005.
29 TEEB 2010.

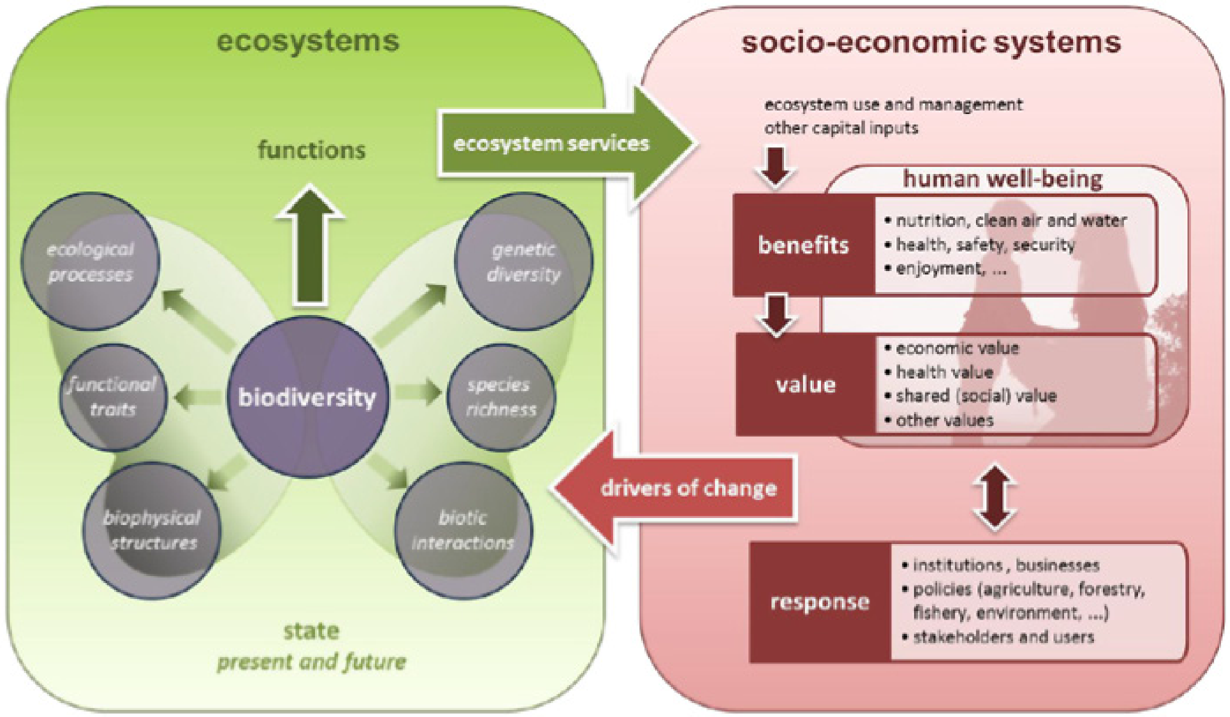
TABLE 2.1 SERVICES PROVIDED BY HEALTHY ECOSYSTEMS

CATEGORY	SERVICE TYPE
PROVISIONAL	Water supply
	Food
	Raw materials
	Medicinal resources
REGULATING	Carbon sequestration and storage
	Moderation of extreme events
	Water purification
	Erosion control
	Pollination
	Biological control
SUPPORTING	Habitat maintenance
	Maintenance of genetic diversity
CULTURAL	Recreation
	Tourism
	Austhetic/cultural value
	Spiritual experience

Note: Highlighted services are directly related to pollution management.

Source: Adapted from TEEB 2010.

FIGURE 2.1 RELATIONSHIP BETWEEN ECOLOGICAL AND SOCIO-ECONOMIC SYSTEMS



Source: European Union 2013.

Ecosystems themselves need a sufficient supply of water, referred to as 'water for nature' in integrated water resources management (IWRM)[30] terminology, to maintain their functions and sustainably provide ecosystem services. Consequently, ecosystem protection and maintenance within a river basin needs to be integrated into water resources management plans in order to enable water quality improvement and natural purification. Ignoring the importance and value of ecosystems and the services they provide can result in the reduction of such services and an associated decline in human well-being.

30 IWRM refers to integrated management of water, adjacent land and related resources as a whole, and is further elaborated in Module 3.

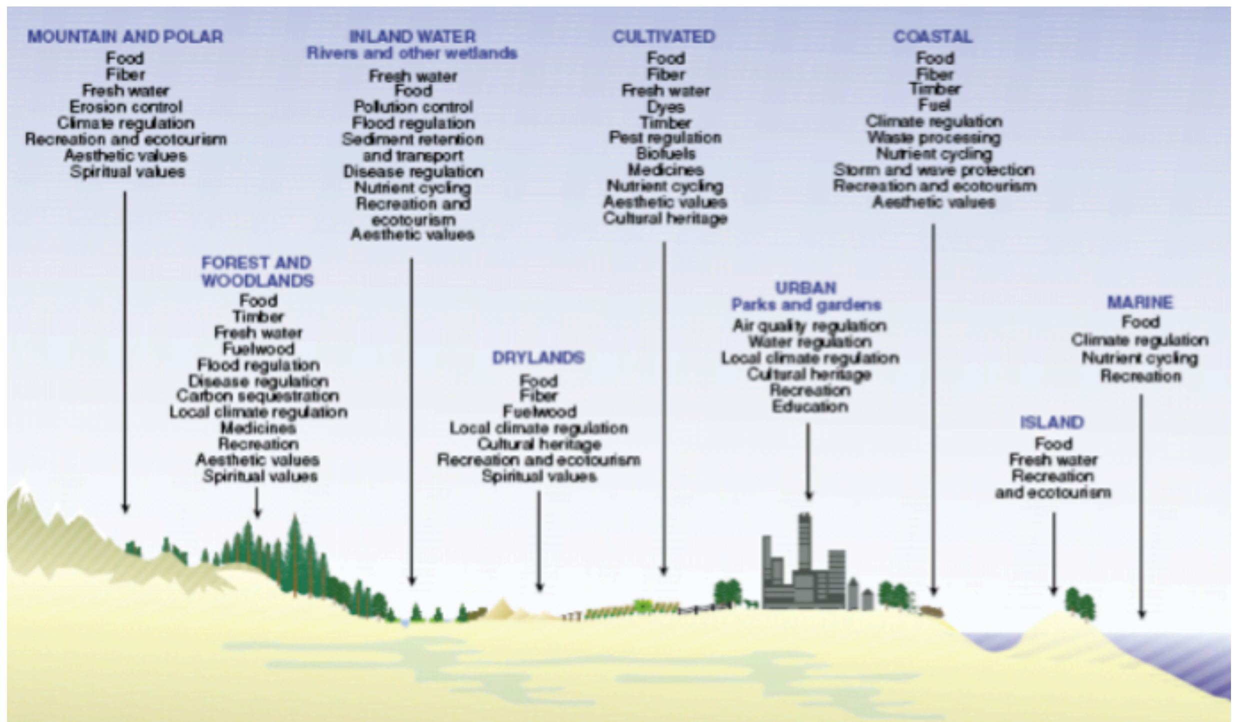
2.1 ROLE OF ECOSYSTEMS IN WATER POLLUTION MANAGEMENT

Ecosystems provide a wide range of services that contribute to water quality regulation (see Figure 2.2). Therefore, water pollution management in a river basin needs to take ecosystems into account. A river basin spans multiple terrestrial and aquatic ecosystems from mountain to sea, including forests, grasslands, rivers and streams, wetlands, lakes, mangroves, estuaries and coral reefs.

Green urban areas are also important to consider in the context of water pollution control. Such natural or semi-natural ecosystems provide services that complement, augment or replace the services provided by built or grey infrastructure (e.g. water treatment plants and dams); they are increasingly referred to as 'green infrastructure'.

A river basin spans multiple terrestrial and aquatic ecosystems from mountain to sea, including forests, grasslands, rivers and streams, wetlands, lakes, man-groves, estuaries and coral reefs.

FIGURE 2.2 ECOSYSTEM SERVICES RELATED TO WATER POLLUTION MANAGEMENT



Source: MEA 2005.

BOX 2.1 EXAMPLES OF ORGANISMS THAT PROVIDE WATER PURIFICATION SERVICES

Phytoplankton (microscopic plants) and **floating plants** in lakes, rivers and the sea can effectively absorb nutrients and heavy metals contained in polluted water. Water hyacinth, for example, may remove over 95 percent of nutrients from domestic wastewater under appropriate conditions.

Soil organisms, including microbes, fungi, earthworms and insects, are crucial to the chemical conversion and physical transfer of essential nutrients to higher plants.

Green mussels and **oysters** filter water for food while at the same time removing nutrients, suspended sediments and chemical contaminants. A single oyster can filter more than 200 litres of water per day.

FOTOLIA

Source: http://www.ramsar.org

2.1.1 Water supply

Healthy ecosystems provide water suitable for drinking and other uses, including agriculture, fisheries, industries, recreation and wildlife.

Wetlands and **forest ecosystems** are particularly vital to freshwater availability and quality at the global scale. Such ecosystems retain and store water in watersheds, supplying it to natural waterways (i.e. rivers and aquifers) and reservoirs. Groundwater aquifers, often recharged through wetlands, play an important role in water supply, with an estimated 1.5–3 billion people directly dependent on groundwater as a source of drinking water.[31] In this way, wetlands and forests regulate and maintain the flow of water required for human activities by storing excess during floods and releasing it during droughts. In some areas, adequate freshwater flows (environmental flows) and groundwater levels are important to combat salt-water intrusion, salinization and acidification.

2.1.2 Water purification

Healthy ecosystems can absorb, retain and recycle pollutants such as sediment, excess nutrients (e.g. nitrogen, phosphorus and carbon), toxicants, metals, viruses, oils and greases (see Box 2.1). Wetlands (including floodplains, riparian forests and other seasonally flooded ecosystems) retain water runoff and floodwater, filter it through soil, sediment and rock strata, and release it to rivers and groundwater aquifers. The Ecological Society of America estimates that healthy wetlands may help to remove 20–60 percent of all metals in the water, 70–90 percent of entering nitrogen and 50 percent of phosphorous.[32]

Excess sediment affects ecosystem health in many river systems. Wetlands serve as sediment traps—pools where sediment can settle before it reaches rivers. Wetland plants, such as reeds and grasses, reduce flow velocity and increase the opportunity for sedimentation. Wetlands

31 WRI 2005.

32 ESA undated.

BOX 2.2 EXAMPLES OF NATURAL WETLANDS PROVIDING WATER PURIFICATION SERVICES

The East Kolkata marshes of India, a patchwork of tree-fringed canals, vegetable plots, rice paddies and fish ponds that support the livelihoods of 20,000 people, is treating one-third of the sewage and domestic refuse from Kolkata (population 10 million) on a daily basis to produce a rich harvest of fish and fresh vegetables.

That Luang Marsh in Vientiane, Lao PDR, Beung Cheung Ek in Phnom Penh, Cambodia, and Bung Makasan in Bangkok, Thailand, are all examples of natural treatment facilities. These wetlands remove excessive nutrients and toxicants from municipal wastewater and sewage. Without these ecosystems, Vientiane, Phnom Penh and Bangkok would have to invest in central wastewater treatment facilities, and a large number of low-income households would lose livelihoods dependent on aquatic plants and fish harvest.

New York City, USA, opted to restore the existing natural wetlands in the watershed that provides the city's best drinking water, rather than to invest in a wastewater treatment facility. The city's wetlands strategy establishes the goals of no net loss of wetlands, improving the quality of the city's remaining wetlands and maximizing their ecological functions to the greatest extent possible.

BOX 2.3 MAN-MADE WETLANDS

Although they cannot replace natural ecosystems or reproduce all of their services, artificial wetlands can offer a cost-effective water treatment solution for small communities and are increasingly used to that end worldwide. The Rouge River area of Michigan, USA, presents an example where nearly two thirds of 6 total hectares of wetlands along the river's banks is man-made, naturally treating storm runoff before it enters the stream. Previously, discharge pipes routed storm water directly to the river. In addition to dampening these flows, artificially expanding the wetlands reduced concentrations of suspended solids by 80 percent, phosphorus by 70 percent, and both oxygen-depleting compounds and heavy metals by 60 percent.

may trap and retain 80–90 percent of sediment from runoff. Although sediment build-up causes shallowness and may alter wetland ecosystem functions and services, the quality of ecosystems downstream will be maintained if suspended sediment is retained in the headwaters.

Toxicants such as industrial and mining discharges and pesticides, particularly persistent organic pollutants, often adhere to suspended sediments. Around the world, natural and man-made wetlands play an important role in purifying water by locking up pollutants in their sediments, soil and vegetation (see Boxes 2.2 and 2.3). Providing purification services can harm ecosystems and the flora and fauna that inhabit them. For example, locked up toxicants can be released back into an ecosystem when plants die and when concentrations or loads exceed an ecosystem's absorption capacity. It is, therefore, crucial to thoroughly understand and properly manage ecosystems as part of broader water resources management, in order to sustain and continue to utilize ecosystem services.

2.1.3 Sediment load reduction

As previously noted, low-lying wetland ecosystems are important sediment sinks. In addition, high-gradient terrain ecosystems, such as forested slopes, prevent soil erosion by effectively locking up potential sediment sources. Similarly, healthy riparian buffer zones prevent riverbank erosion, reducing downstream sediment pollution.

UN PHOTO/SYLVAIN LIECHTI

DISASTER IMPACT MODERATION

Healthy ecosystems often reduce the impact of extreme natural events. Mangrove forests act as buffers against the sea, moderating the impact of coastal storms and surges on neighbouring inland ecosystems and communities—and, important to water quality, limiting saltwater intrusion and soil erosion, which causes sediment to enter water streams. Further, many ecosystems store rain and flood waters, not only further reducing soil erosion but also minimizing the frequency and magnitude of floods that result in sewage overflows—the central cause of water pollution in urban areas.

LOCAL CLIMATE REGULATION

Water temperature is a master variable that directly and indirectly affects aquatic ecosystems and their ability to provide water purification services. Riparian forests, and forests in general, provide shade and reduce water temperatures, reducing the impact of thermal pollution.[33] A recent study found that relatively short stretches of riparian forest (100–500 metres) are sufficient to cool overheated water streams.[34]

BIOLOGICAL THREAT CONTROL

Healthy ecosystems are typically able to control pests, invasive species and vector-borne diseases. Ecosystems regulate such pollutants through predator and parasite activity. Biological control depends on very sensitive interactions among different species inhabiting ecosystems, and this delicate balance is easily disturbed. While potentially useful, using ecosystems' inherent biological control mechanisms for pollution management must be based on solid knowledge of the ecosystem, its assimilative capacity and tolerance.

33 Thermal pollution is the degradation of water quality as a result of any process that changes ambient water temperature. A common cause of thermal pollution is the use of water as a coolant by power plants and industrial manufacturers.

34 Kristensen et.al. 2013.

DISCUSSION QUESTION

How can ecosystems be used for reducing water pollution?

2.2 WATER POLLUTION IMPACTS ON ECOSYSTEMS

Many ecosystems store rain and flood waters, not only further reducing soil erosion but also minimizing the frequency and magnitude of floods that result in sewage overflows—the central cause of water pollution in urban areas.

Over the past 50 years, humans have dramatically changed the world's ecosystems. Degradation and loss of wetlands is more rapid than that of other ecosystems.[35] The Living Planet Index shows that between 1970 and 2005, freshwater species population cut in half—a clear sign of ecosystem degradation on a global scale.[36]

Physical modification and fragmentation of river systems and associated wetlands are the main causes of degradation. Numerous additional pressures can distress aquatic ecosystems; for example:

- Surface and groundwater **over-withdrawals** result in lowering water levels;
- Increased **suspended solids and siltation** preclude adequate sunlight penetration and disrupt the growth of water-dwelling species of photosynthetic plants, invertebrates and microorganisms. Increased suspended solids may also result in eutrophication-like impacts;
- Increased **nutrient runoff and eutrophication** cause an over-growth of algae and aquatic plants, not only clogging rivers and waterways and blocking sunlight, but also using up dissolved oxygen as they decompose. Many types of fish, bottom-dwelling animals and other aquatic species cannot survive when levels of dissolved oxygen drop. If death occurs in large numbers, disruptions in ecosystem food chains and species extinction may occur;

35 WRI 2005.
36 WWF 2015.

UN PHOTO

- **Heavy metals and chemical pesticides, particularly persistent organic pollutants**, oils, radioactive waste and various pathogens (including bacteria, viruses and protozoan) can be deadly to aquatic life and can affect the rest of the food web and chain, including the top consumers—people. Microbial pollutants can result in infectious diseases that spread among aquatic and terrestrial life through drinking water;
- **Acidification**, caused by sulphuric and nitric acid deposits from the air and acidified (drained) soil, affects ecosystems both directly (as all species have tolerance limits) and indirectly, by increasing the mobility of toxic components such as heavy metals (e.g. arsenic);
- **Salinization**, caused by saltwater intrusion or saline runoff from terrestrial areas affected by salinization, harms ecosystems by reducing available freshwater and stressing freshwater life. The reduction of high flow events (flushing) may exacerbate salinization of aquatic ecosystems;
- Introduction and spread of **non-indigenous invasive species**; and
- **Rising water temperatures**, brought about by land use and climate change, lower dissolved oxygen amounts, change precipitation and water flows, and cause saline intrusion into freshwater ecosystems as sea level rise.

All types of water pollution have adverse effects on natural ecosystems and the services they provide. Such effects may be far removed from the pollution source in time and space but typically include **on- and off-site effects** on ecosystems and resource users (i.e. impacts at the source of and downstream of pollution), **immediate irreversible effects** and **long-term accumulated effects**.

DISCUSSION QUESTION

To what extent has water pollution management paid attention to ecosystems in your country?

2.2.1 Pollution-related concepts and processes in aquatic ecosystems

Pollutants that enter aquatic ecosystems have different fates and destinations, depending on pollutants' properties and the conditions, components and processes within water bodies. Specific ecosystems' properties and functions should underpin local water pollution management. These range from an ecosystem's elevation to its tolerance levels and adaptive or rehabilitative capacity, as outlined in this section.

Upstream–downstream connection. Water flows from high to low ground. If the water of a river is polluted at a certain location, pollutants must have flowed into the river from a location with higher elevation. Pollutants that enter a river affect downstream water quality and ecosystems. The upstream–downstream relationship also affects water quantity and uses.

Environmental flows. Water is vitally important to ecosystem dynamics. Both surface and groundwater ecosystems need upstream freshwater inputs to maintain the functions, services, uses and benefits they provide. The amount of water needed to maintain ecosystem health is referred to as its 'environmental flow'. To prevent degradation and destruction of ecosystems and ensure ecosystem services, it is important to meet ecosystems' environmental flow requirements with quality water and appropriate seasonal variability.

Dilution. Many substances can dissolve in water. Some may be diluted and transported with flow, while others may settle and deposit at different sites within an ecosystem or be transported downstream beyond it.

Biomagnification. Within aquatic ecosystems, pollutants can be accumulated and transferred up the food chain, posing a danger to human health through such biological magnification (see Figure 2.3). This process is critical to water pollution management, particularly to establishing water quality standards and environmental licenses. Even small amounts of certain pollutants released into ecosystems can have deadly effects on their inhabitants and users, including humans. The best example is Dichlorodiphenyltrichloroethane (DDT), which was used as an insecticide but ultimately banned in many countries due to increasing concentrations moving up the food chain.

FIGURE 2.3 EXAMPLE OF BIOLOGICAL MAGNIFICATION WITHIN AN AQUATIC ECOSYSTEM

FIGURE 2.4 DOSE–RESPONSE–HARMFUL EFFECT: THRESHOLD LEVEL

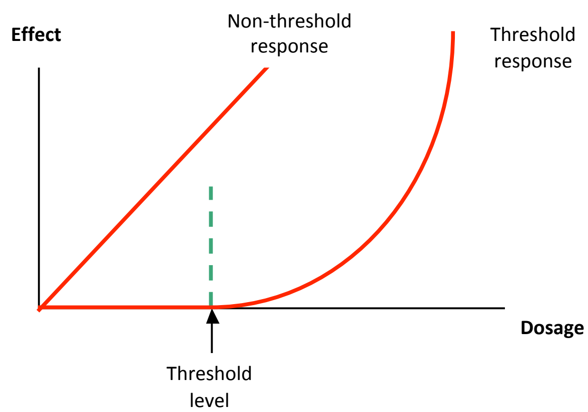
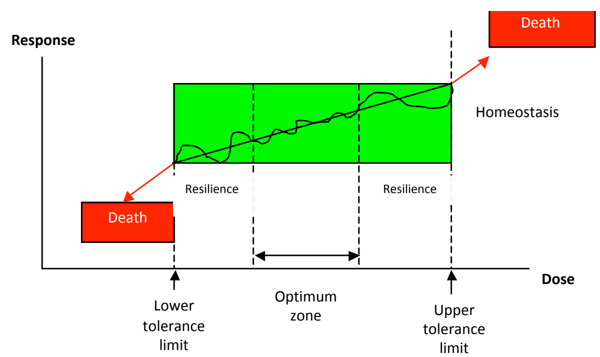


FIGURE 2.5 ECOSYSTEM HOMEOSTASIS, RESILIENCE AND TOLERANCE LIMITS



Synergy and synergistic effects. Multiple distinct pollutants within a water body can act synergistically, exacerbating or multiplying total ecosystem impacts beyond additive pollutant impacts. A relatively harmless pollutant can become extremely toxic when mixed with another pollutant.

Threshold levels. Some pollutants, including mercury (Hg), cadmium (Cd) and lead (Pb), are non-threshold agents and are potentially harmful to aquatic life in any amount. Nitrates, phosphates and organic waste are threshold agents and become harmful above certain concentrations or threshold levels (see Figure 2.4). Understanding pollutant characteristics is necessary for appropriate management action—for example, setting up ambient water quality objectives and effluent quality standards.

Homeostasis, resilience, and tolerance. Ecosystems differ greatly in their resilience, including resistance to water pollution or quality degradation. Natural ecosystems can act buffers for fluctuating pollutant loads, but assimilative capacity is limited. Ecosystems can adapt or adjust themselves to some extent but can collapse under pollution loads beyond natural resilience (lower or upper tolerance limits), with potentially irreversible damage that precludes recovery or rehabilitation (see Figure 2.5). Therefore, wetland ecosystems can provide treatment of domestic wastewater from small non-industrial communities or serve as tertiary wastewater treatment facilities—but should not be used for primary or secondary treatment of industrial waste.

2.2.2 Ecosystem approach to water pollution management

The United Nations Environment Programme (UNEP) defines the ecosystem approach as 'a strategy for the integrated management of land, water and living resources that provides sustainable delivery of ecosystem services in an equitable way'.[37] There are 12 principles to the ecosystem approach, referred to as the Malawi Principles based on the location of the 1998 workshop that formulated them before their adoption by the Convention of Biological Diversity later that year (see Box 2.4).

37 UNEP 2009.

BOX 2.4 THE MALAWI PRINCIPLES OF THE ECOSYSTEM APPROACH

- The objectives of management of water, land and living resources are a matter of societal choice.
- Management should be decentralized to the lowest appropriate level.
- Managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems.
- Recognizing potential gains from management, there is usually a need to understand and manage the ecosystem in an economic context.
- Conservation of ecosystem structure and functioning, to maintain ecosystem services, should be a priority target.
- Ecosystems must be managed within the limits of their functioning.
- Ecosystem approach should be undertaken at the appropriate spatial and temporal scales.
- Recognizing the varying temporal scales and lag-effects that characterize ecosystem processes, objectives for management should be set for the long term.
- Management must recognize that change is inevitable.
- The ecosystem approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity.
- The ecosystem approach should consider all forms of relevant information, including scientific, indigenous and local knowledge, innovations and practices.
- The ecosystem approach should involve all relevant sectors of society and scientific disciplines.

Source: CBD 1998.

In water pollution control and management, the ecosystem approach takes the form of utilizing existing or potential ecosystem services for cost-effective water purification, while avoiding ecosystem degradation. When implementing the ecosystems approach in an IWRM context, it is important to ensure:

- **River basin-based management.** Water resources and pollution do not respect political or administrative boundaries, making a river basin-based management unit most appropriate for water pollution control and water quality management.
- **Protection and restoration of the natural and semi-natural ecosystems** that provide needed services. This includes:
  - ensuring adequate environmental flows in the context of IWRM (i.e. balancing human and ecosystem needs for water quantity and quality); and
  - ensuring pollution does not exceed ecosystems' maximum assimilative capacity (i.e. capacity to receive waste loads and discharges).

UN PHOTO/KIBAE PARK

- **Reduction of risks and uncertainties**. In-depth information on and understanding of the linkages among ecosystem functions, services and resilience is required to ensure sustainable solutions.
- **Adaptive management.** Knowledge pertaining to ecosystem use and management for pollution control is still evolving. Management must, therefore, be flexible enough to adapt new information as it becomes available. Ecosystem management may be envisaged as a long-term experiment that builds on its results as it progresses.
- **Stakeholder participation.** Human activities take place not outside but inside of ecosystems. Stakeholder participation in both ecosystem management and water pollution control is vitally important to ensure human activities do not harm ecosystems and specifically avoid water pollution.
- **Combined use of green and grey infrastructure.** Pollution management should consider both ecosystem-based (i.e. green) and man-made (i.e. grey) infrastructure solutions, which help to breakdown various substances in wastewater and enable them to be treated by ecosystems.
- **Inter-sectoral cooperation** is important when planning and managing land and water use within a river basin, taking into account the causes and effects of water pollution on ecosystems, as well as the role of ecosystem services in water pollution control.

To ensure a realistic and balanced implementation, it is important that the ecosystem approach to pollution management is embedded within an overarching IWRM framework (see Module 3).

KEY MESSAGES

- **Healthy ecosystems provide a wide range of services that contribute to human well-being, including water supply and purification, moderation of extreme weather events, erosion control and local climate regulation.**
- **Ecosystem services may provide a cost-effective solution to water treatment and pollution control. These and other green infrastructure solutions must be considered in water pollution management, because they often yield valuable additional benefits.**
- **Ecosystems have limited supportive and assimilative capacities. It is important to respect ecosystem tolerance limits, in order to ensure the sustainability of ecosystem services.**
- **Healthy ecosystems rely on adequate environmental flows, the management of which is an important component of IWRM referred to as 'water for nature'.**
- **The ecosystem approach should be integrated into the broader IWRM framework at the river basin level.**

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LEARNING OBJECTIVES

In this module, participants will learn to:

- **Describe the integrated water resources management (IWRM) concept and principles;**
- **Recognize pollution control strategies as an essential element of IWRM; and**
- **Identify IWRM benefits for all pollution management stakeholders.**

MODULE 3

Pollution management as part of integrated water resources management

A holistic or integrated approach to water resources management has been promoted at the global level to address the full spectrum of problems being experienced as a result unsustainable use. In many countries, water sector reforms are progressing to adopt IWRM concepts; however, in practice, countries focus mainly on managing water quantity rather than quality. Greater attention should be placed on addressing water quality as part of IWRM, which underscores linkages among different elements of the water environment and promotes an equally integrated approach to resolving problems—pollution included.

Water pollution is everyone's concern, a cumulative effect not belonging to a single person or sector. Though best managed at the lowest—catchment or basin—level, water pollution impacts all aspects and levels of water management and use. Pollution affects water resources allocation for different uses, illuminating a strong connection between upstream and downstream users; devising solutions requires engaging the many stakeholders involved and working at an appropriate scale.

DISCUSSION QUESTION

How should pollution management be 'integrated' in water resources management?

3.1 IWRM RELEVANCE TO POLLUTION CONTROL

3.1.1 IWRM definition, foundational principles and goals

A paradigm shift in the water sector, IWRM is an approach that promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems. The basis of IWRM is that many different uses of water resources are interdependent in quantity and quality. One usage can constrain others by limiting access to not only adequate amounts of water, but also to safe water. All water users are potential polluters, adding substances to water that make it unfit for further use. Therefore, a well-coordinated and regulated framework is necessary for sustainable water resources management. As such, integration is the central concept of IWRM, entailing the challenge of coordinating among various government, academic, industrial and civil society stakeholders.

The need for a participatory approach to addressing water scarcity was identified by the 1992 International Conference on Water and the Environment, which produced the Dublin Principles that also highlighted the gender and economic dimensions of water management and formed the foundational *principles* for IWRM implementation (see Box 3.1).

IWRM *goals* focus on delivering 'the Three Es': Economic efficiency, social Equity, and Environmental sustainability (see Sections 3.2.2 and 3.2.3).

BOX 3.1 IWRM PRINCIPLES

The Dublin Statement on Water and Sustainable Development was formulated during the 1992 International Conference on Water and the Environment in Dublin. The statement contained a set of recommendations that became known as the Dublin Principles, which form the basis for IWRM implementation:

- **Freshwater is a finite and vulnerable resource, essential to sustain life, development and the environment;**
- **Water development and management should be based on a participatory approach, involving users, planners and policymakers at all levels;**
- **Women play a central part in the provision, management and safeguarding of water; and**
- **Water has an economic value in all its competing uses and should be recognized as an economic good as well as social good.**

Source: ICWE 1992.

3.1.2 IWRM principles' relevance to pollution control

IWRM recommends managing water at the lowest appropriate level—the river basin or catchment. It is fundamental and easy to recognize that pollution incidents occur largely at the basin or catchment level, as drainage systems carry contaminant loads. Water pollution can often be linked to decisions made regarding development within a basin. Consequently, it is logical to align pollution control with overall water resource management and, to the extent possible, use the same institutional structures for both basin development and water pollution control programmes.

DISCUSSION QUESTIONS

Who are the key players in integrating water pollution control into water resources management? What are their interactions and potential ways of working together to solve the water pollution issue?

PRINCIPLE 1: WATER IS A FINITE AND VULNERABLE RESOURCE

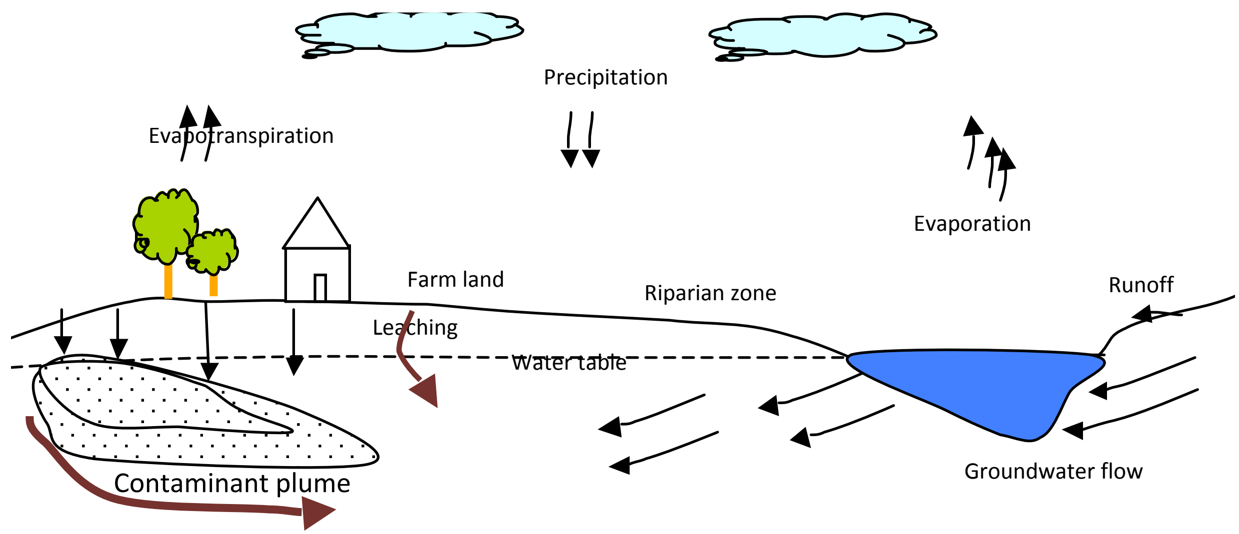
IWRM principles recognize that water is a scarce resource used for many different purposes, functions and services; therefore, water management has to be holistic and carefully consider different demands in view of available resources—and threats.

The cycle of hydrological processes sustains life on earth but yields a somewhat fixed quantity of water. Freshwater is a natural asset that must be protected to ensure that the essential services it provides continue. IWRM principles recognize that water is a scarce resource used for many different purposes, functions and services; therefore, water management has to be holistic and carefully consider different demands in view of available resources—and threats. Water resource management encompasses seeking non-conventional water sources, such as reclaimed or desalinized water. Addressing source-point pollution (i.e. precluding waste streams from entering natural water bodies) is among measures that address water scarcity.

Water is a unique life-supporting substance that is easily polluted, because it is:

- Interconnected in all three states (gas, liquid and solid) and locations (air, surface, ground);
- Used in multiple ways: drinking, health and sanitation, irrigation, industries, ecosystem maintenance, etc.;
- A universal solvent; and
- Excellent media for mass and energy transfer.

FIGURE 3.1 THE WATER CYCLE

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Water flow quantity and substance transfer rates can be influenced by vegetation cover, forest trees, shrubs and grass (interception). When water flows (see Figure 3.1), it also dissolves and carries many substances that are discharged into:

- Atmosphere to land (precipitation);
- Over the land surface (runoff);
- Surface to groundwater (infiltration and percolation);
- Land to atmosphere (evapotranspiration);
- Upstream to downstream (stream flow and seepage);
- Stream to ocean (drainage); and
- Ocean to atmosphere (evaporation).

BOX 3.2 CONFLICT IN INDIA

Palar River in India, is the source of drinking water for 30 towns and 50 villages on its banks and also used for the cultivation purpose. In the Palar basin, Tannery is a major industry that provides employment to 2 million workers. At the same time, the basin's small-scale farmers depend on groundwater for agriculture and personal consumption. The tanneries present on the banks allowed effluents in the Palar River as a result the Palar River became more polluted recently and no longer useful for drinking or agricultural purposes. Due to pollution, peoples around the river are suffering from a number of diseases such as asthma, skin disease and stomach ailment and thousands acres of fertile land have become wasteland and no more used for cultivation. The Ranipet, an industrial area present in the bank of Palar river was reported as the most polluted places of world by Blacksmith Institute in 2006, which are heavily contaminated with salts and heavy metals especially Chromium. Elevated chromium concentration in the effluents from tanneries poses a serious environmental concern in Vellore district, home of innumerable small and large-scale tanneries.

The affected communities filed a lawsuit and received compensation and a court order for setting up common effluent treatment plants, but not much progress has been made on the latter by the government. Civil society organizations indulged in agitations to encourage speedier action. The uncoordinated activities of many stakeholders, including the government, created chaos in the basin.

Source: Sundar et al. 2010.

Water ecosystems can absorb a certain amount of pollution without damage, with absorption capacity varying based on water volume, pollutant concentrations and quantity and other such factors. Water systems with highly variable seasonal flows can, therefore, change from slightly polluted to seriously polluted during the course of a year.

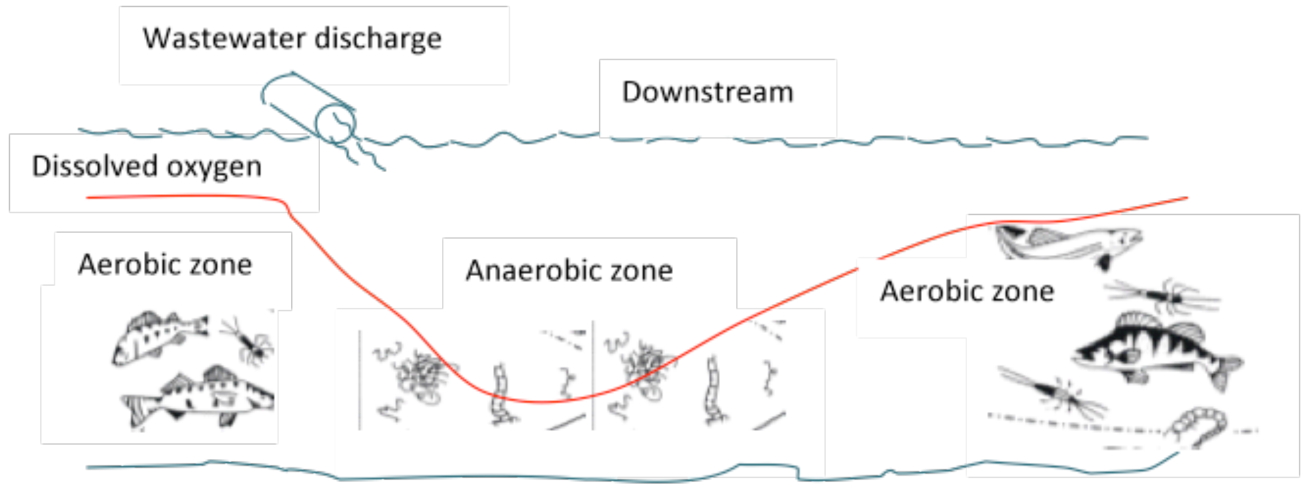
Rainfall and wetlands recharge groundwater supply. Groundwater contamination is more localized and less frequent, because flow velocity is often low and soil acts as a filter. Nevertheless, once groundwater is polluted, it may take hundreds or thousands of years to become clean. Understanding the link between surface and groundwater is important for water pollution management, because polluted surface water can easily contaminate groundwater through recharge.

PRINCIPLE 2: THE NEED FOR A PARTICIPATORY APPROACH

Any upstream action may have an impact on downstream water users. Mining, forest clearance or irrigation may each have distinct unintended consequences for communities and environments located elsewhere in the basin. Dissolved oxygen concentrations decrease rapidly at the point of wastewater discharge, creating a septic environment that greatly distresses aquatic systems (see Figure 3.2). The severity and reach of downstream impact depend on multiple factors (e.g. pollutant concentrations, flow velocity, water volume, vegetation, climate). Water pollution by upstream users deprives downstream users and the ecosystems of their legitimate right to a shared resource, requiring a stakeholder dialogue to reconcile the needs of upstream and downstream users.

Water pollution is an area of conflict among polluters, regulators, environmental activists and the public affected by their actions (see Box 3.2). Eliminating such conflict or finding solutions to water-related problems can only be possible if all interested parties come together at the outset of any activities that impact water availability and quality.

FIGURE 3.2 DISSOLVED OXYGEN DEPLETION CURVE IN A STREAM DUE POINT SOURCE POLLUTION



Stakeholder participation creates an enabling environment for economic, environmental and social development. Similarly, addressing water quality issues can benefit from establishing and nurturing productive partnerships among stakeholders in all functions of water pollution management—including risk assessment, setting water quality objectives and effluent quality standards, licensing, monitoring and information-sharing.

PRINCIPLE 3: IMPORTANT ROLE OF WOMEN

Historically women have played a considerably less influential role than men in managerial, analytical and decision-making processes of the water sector.

The gender dimension of IWRM requires special emphasis, because historically women have played a considerably less influential role than men in managerial, analytical and decision-making processes of the water sector. At the same time, women's domestic and communal responsibilities often make them more vulnerable to water-related threats. It is, therefore, important to improve women's access to decision-making and ensure their active involvement in all IWRM issues, including water pollution.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Water pollution has gender-differentiated impacts, because of women and men's different roles in society. For example, as the custodians of family health and hygiene and providers of domestic water, women are the primary stakeholders in household water use. As such, women of developing countries are likely to consider water quality more important than men, have more experience with pollution impacts and be in the position to make significant contributions to pollution control strategies and their implementation. From another perspective, women as managers of household consumption can play a leading role in waste management at the household level. Women's roles in pollution management may include:

- Polluters (as consumers, waste generations—to be targeted for reducing pollution);
- Water resources protectors;
- Monitors of water pollution and effluent quality standards;
- Implementers of catchment conservation for safe water supply;
- Decision makers for water quality objectives; and
- Planners at national or river basin level.

PRINCIPLE 4: WATER AS AN ECONOMIC AND SOCIAL GOOD

Water is a national development resource that must be used efficiently to reach socio-economic objectives. Managing water as an economic good is an important tool to ensure efficient use of a scarce resource and maximize economic impact. However, access to clean water and sanitation is a basic human right, hence water decisions must carefully balance economic and social considerations.

The polluter-pays principle in pollution control is a financial tool that encourages polluters to treat wastewater prior to discharge or implement other methods of eliminating or mitigating a specific polluting behaviour. The underlying concept is that polluters should bear the cost of carrying and managing their pollutants, monitoring and permit systems required to supervise

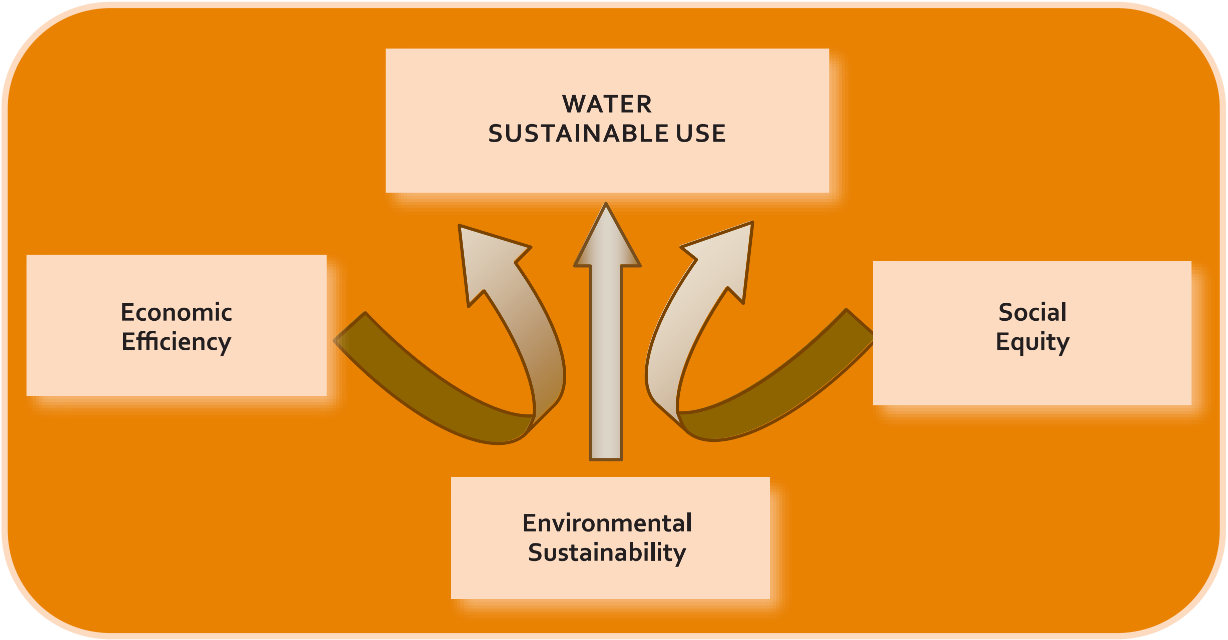
The polluter-pays principle in pollution control is a financial tool that encourages polluters to treat wastewater prior to discharge or implement other methods of eliminating or mitigating a specific polluting behaviour.

their activities. In theory, no one should pollute; however, this is practically impossible in most countries and systems. The pragmatic goal is to define and enforce acceptable pollution limits and gradually work towards a cessation of all polluting activities by applying appropriate treatment methods before discharging wastewater into the environment.

3.1.3 IWRM goals' relevance to pollution control and water quality management

Successful IWRM implementation ensures sustainable development alongside desirable socio-economic development by prioritizing Three Es: social Equity, Environmental sustainability and economic Efficiency (see Figure 3.3).

FIGURE 3.3 THREE PILLARS OF IWRM GOALS

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Social equity requires that a fair share of benefits and responsibilities be transmitted to women and men, the poor and the rich, the young and the old. In the water sector, social equity means fair opportunity to access, use and control water resources, as well as equitable sharing of responsibilities for the negative side-effects produced, so as to avoid a disproportionate burden on the poor or otherwise disadvantaged members of society.

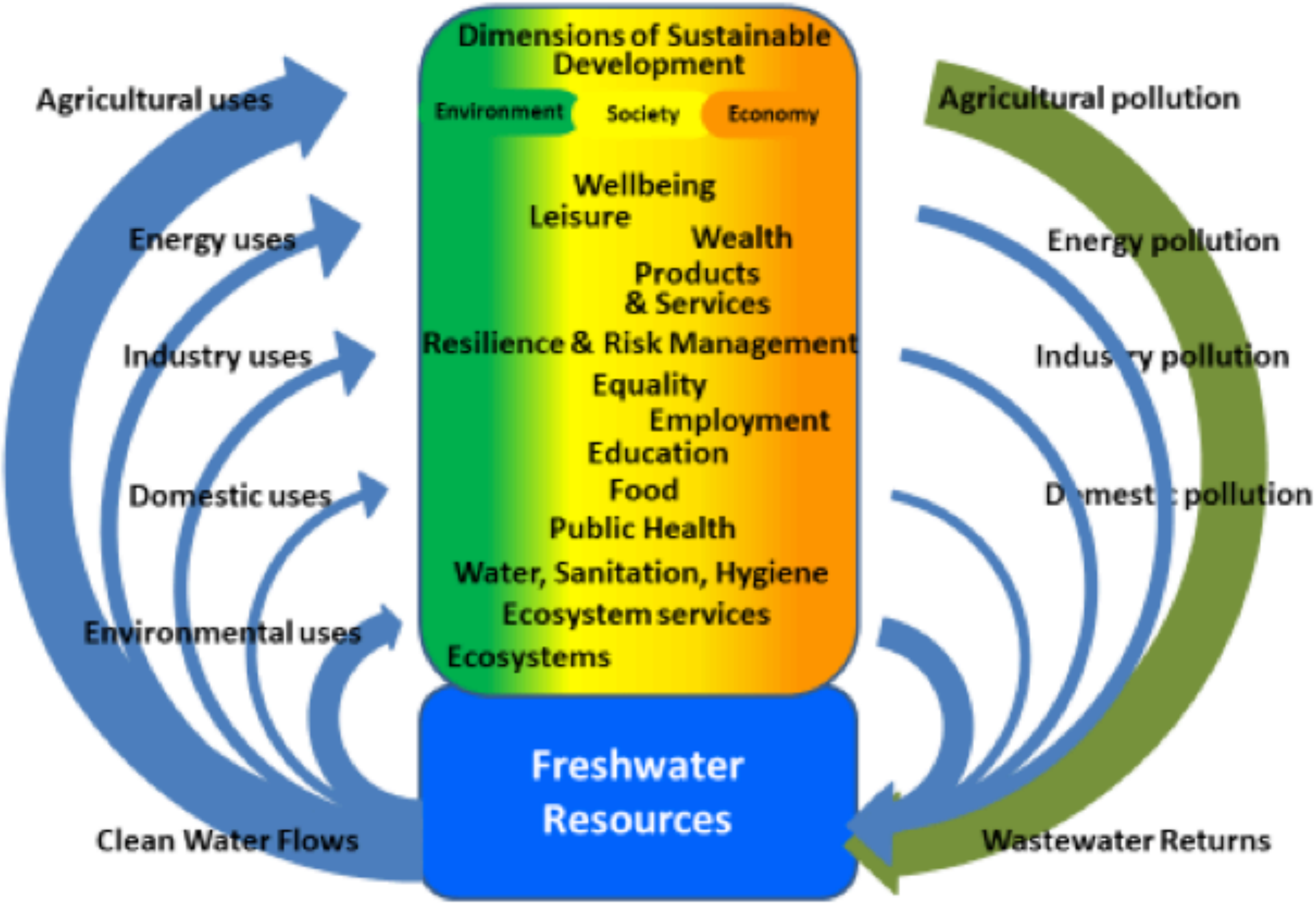
Many countries fall short of the social equity standards. Water pollution can affect entire societies, but it is the poor who most often lack access to clean drinking water, the decision-making processes that contribute to its scarcity and opportunities to remedy such problems—while the benefits of water use for production and waste disposal (i.e. pollution-generating activities) do not favour the bottom of the social pyramid.

Environmental sustainability means protecting nature's capacity to support life. In the IWRM context, this means ensuring the health of the water cycle, reserving adequate water for natural processes and reducing water pollution. Forests and wetlands, among other ecosystems, help regulate water flow and quality and must be conserved in order to sustain a healthy water cycle.

The relationship between environmental conservation, and social and economic development can be very complex. In an economic policy context, environmental objectives are often given no real expression either within institutions or among decision makers—and water is among the most affected environmental sectors as a consequence. When economic policies aim for rapid economic growth but do not prioritize environmental sustainability, water-polluting activities are tolerated with considerable, often severe, consequences for water quality, the environment and human health.

Economic Efficiency is a valuable criterion for water-related decision-making. Water is vital to sustaining and growing urban and rural livelihood activities. Given increasing water scarcity, its allocation and management become central to maximizing social and economic benefits and ensuring sustainability.

FIGURE 3.4 UNDERSTANDING THE SMALL WATER CYCLE AS FOUNDATION OF SUSTAINABLE DEVELOPMENT



Source: UNEP unpublished resources.

The big natural water cycle supports numerous smaller man-made water cycles that critically alter overall water availability. Better management—i.e. improved economic efficiency—of these man-made water cycles is required to ensure sustainable development.


UN PHOTO/M GUTHRIE

There is not much that mankind can do to change water availability in the natural water cycle. However, this big natural water cycle supports numerous smaller man-made water cycles that critically alter overall water availability (see Figure 3.4). Better management—i.e. improved economic efficiency—of these man-made water cycles is required to ensure sustainable development. Reducing pollution and collecting, recycling and reusing wastewater are some of the obvious first steps.

The results of increased economic efficiency can produce:

- More water for allocation (e.g. by reducing pollution to increase usable water quantities, by using reclaimed water);
- Cost savings, by delaying or eliminating the need for new infrastructure;
- Reduced environmental pollution;
- Improved economic returns from agricultural and industrial water uses; and
- Greater economic development.

DISCUSSION QUESTION

Can you give examples of where pollution management should contribute to achieving the Three Es?

3.1.4 IWRM change areas

Many countries are reforming water management to align with IWRM principles and goals. Successful IWRM implementation, including pollution management measures, requires engagement in three areas:

- Enabling environment;
- Institutional arrangements; and
- Management instruments.

Community structures can be very effective in both water management and pollution control, particularly in cases of groundwater that government institutions are unable to reach given the large number of scattered abstraction points.

3.1.5 The enabling environment in pollution control

Pollution-sensitive national water policies supported by a legislative framework and financing and incentive structures create an enabling environment for pollution control. National policies and legislation on environmental conservation and protection of natural resources should be examined for water pollution control strategies, catchment protection plans and other measures that aim to improve or preserve water quality. Specifically needed are laws, regulations and permit or licensing systems for wastewater discharge, with oversight and sanctions against non-compliant polluters.

From an institutional standpoint, water resources management functions and pollution management functions are typically handled by different government bodies. An agriculture, energy or water ministry typically handles water resources, while an environmental government agency oversees pollution control. One important outcome of the IWRM approach is the recognition of a common interest in pollution management among different stakeholders and the establishment of an effective system that integrates and coordinates everyone's needs, resources and actions, thereby creating an enabling environment.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3.1.6 Institutional arrangements in pollution control

The basin level is most appropriate for water management, because decisions' impact is evident up and downstream considerably more than across river basins and decisions should be made where the impact will be felt. Following the same logic, control and management of water pollution should be decentralized but closely coordinated among basin-level systems and organizations managing water—and specifically water pollution.

Community structures can be very effective in both water management and pollution control, particularly in cases of groundwater that government institutions are unable to reach given the large number of scattered abstraction points. An institutional framework with the regulatory function of a government body and a public-private partnership with adequate human and financial support are necessary to implement water pollution control measures. Water pollution management should be a key mandate and responsibility of all river basin management bodies, committees and authorities; pollution management may be further decentralized to multiple basin communities that may develop locally specific rules, laws and agreements.

An institutional framework with the regulatory function of a government body and a public-private partnership with adequate human and financial support are necessary to implement water pollution control measures.

3.1.7 Management instruments in pollution control

At the operational level, all IWRM instruments have relevance to pollution control. Examples of management instruments in pollution control include:

- Water resources assessment encompassing the quality of surface and groundwater;
- Participatory and inclusive monitoring and decision-making;
- Polluter-pays, monitoring and sanction systems that control polluting behaviour;
- Basin-level integration of pollution control instruments into development and water management plans;

- Progress monitoring systems that observe the water pollution trend over time and measure the effectiveness of control measures;
- Information systems that make water quality information available to affected communities and other stakeholders; and
- Water quality guidelines, such as the WHO 2006 Guidelines for the safe use of wastewater, excreta and greywater,[38] US Environmental Protection Agency Effluent Guidelines,[39] and wastewater reuse or country-specific adapted guidelines.

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3.2 PLANNING FOR WATER POLLUTION MANAGEMENT

Defining water quality standards and establishing pollution management systems must be integrated into river basin planning at the outset, along with all other aspects of basin management where water, land and other related resources are integrated and coordinated. Integrated management means that all the different polluters (point and non-point) and water users are considered together. IWRM emphasises that we must not only focus on development of water resources, but also must consciously manage water in a way that ensures its long-term sustainability for use by future generations.

The guiding principles for water pollution control promote proactive mechanisms that prevent or reduce pollution and amicable solutions accepted in the prevailing context before stringent regulations (see Table 3.1).[40] Effectiveness—that is, minimizing pollution—requires the recognition, coordination, and sustained engagement of multiple water stakeholders, local ownership and implementation, and financial resources.

38 See www.who.int/water_sanitation_health/wastewater/gsuww/en.

39 See https://www.epa.gov/eg.

40 UNEP 1997.

UN PHOTO/IRWANDI M GADE

TABLE 3.1 GUIDING PRINCIPLES FOR WATER POLLUTION MANAGEMENT

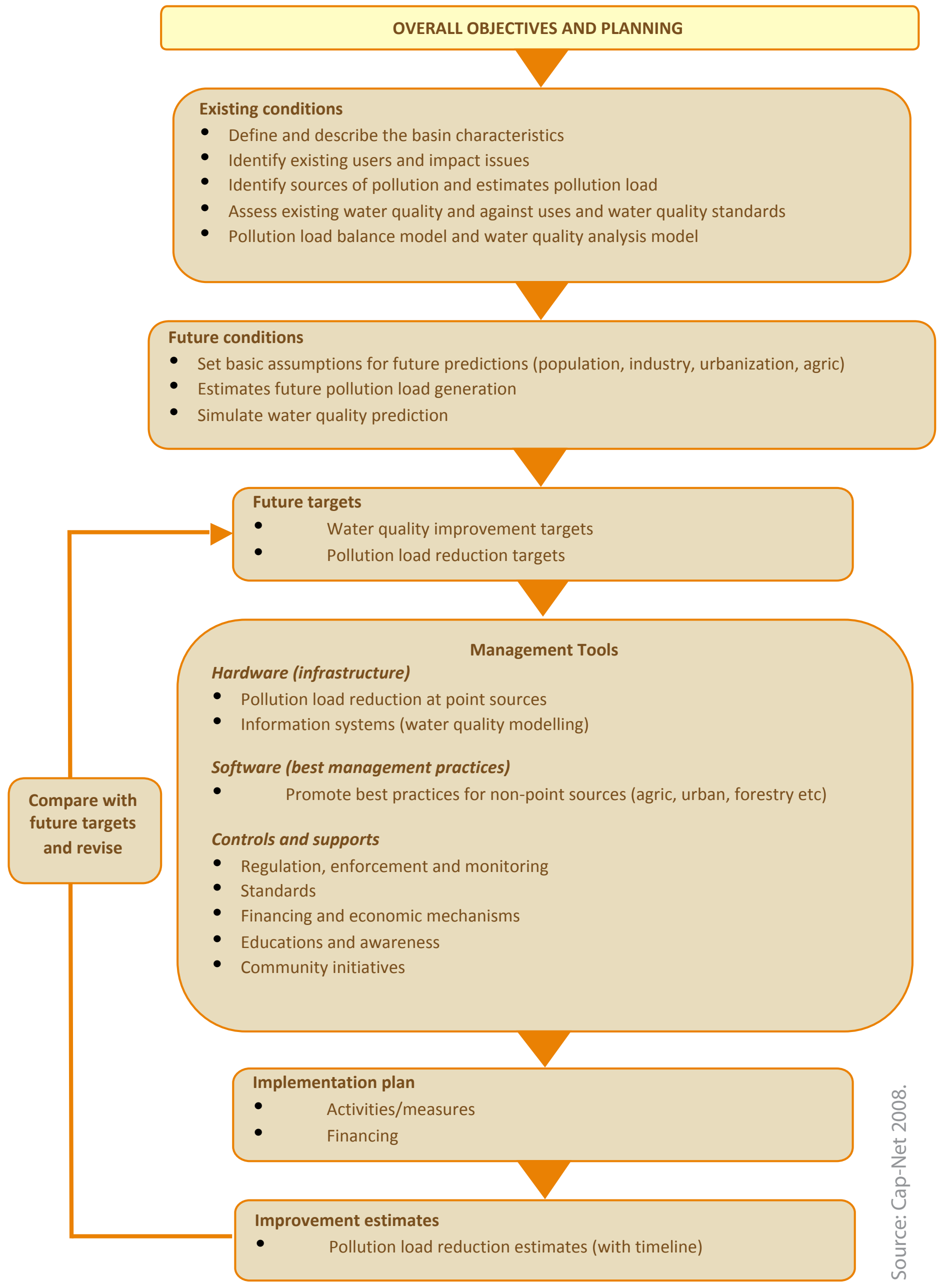
IWRM PRINCIPLES	WATER POLLUTION MANAGEMENT PRINCIPLES
Water is a finite and vulnerable resource	Use the precautionary principle: abandon the use hazardous substances (pesticides).
	Concern multiple use and reclaimed water use (reuse of treated wastewater) in agriculture and ecosystems.
The need for a participatory approach	Apply realistic (achievable and enforceable) standards and regulations.
	Involve all relevant stakeholders.
	Provide open access to information on water pollution.
	Establish cross-sectoral integration mechanisms.
	Promote international cooperation on water pollution control.
Important role of women	Engage at the lowest appropriate level. Take into account how gender matters in pollution management.
Water as an economic and social good	Prevent pollution rather than remedy it (clean-up and mitigation are much more expensive than preventing or minimizing non-point source pollution).
	Apply the polluter-pays principle to facilitate point-source pollution reduction.
	Balance economic and regulatory instruments.

Effectiveness—that is, minimizing water pollution—requires the recognition, coordination, and sustained engagement of multiple water stakeholders, local ownership and implementation, and financial resources.

Figure 3.5 presents an overview of preparing a pollution control plan in the context of a river basin. The planning process considers the assessing of existing conditions with future predictions, setting targets for improvements and to avoid future risks, suggesting appropriate management tools, implementation tools and performance monitoring.

Water pollution is a complex multidimensional issue. Pollution's impacts on water resources and, consequently, human and environmental well-being, demonstrate that water resources and water quality should be managed together, with an effective mechanism for cooperation among responsible agencies and relevant stakeholders.

FIGURE 3.5 PLANNING PROCESS FOR POLLUTION MANAGEMENT IN A RIVER BASIN



Source: Cap-Net 2008.

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PART II

An enabling environment for preserving water quality

LEARNING OBJECTIVES

In this module, participants will learn about:

- **Internationally accepted principles that underpin water pollution control and management;**
- **The policy, legislative and institutional framework that supports and facilitates water pollution management activities; and**
- **Appropriate institutional frameworks for water pollution management.**

Note to facilitator: This module, important to starting the practical application of the course, stimulates a lot of interaction. Therefore, more time can be allocated to discussion if the programme allows.

UN PHOTO/KIBAE PARK

MODULE 4

Policy, legislative and institutional framework

Water pollution management aims to protect the environment for the good of the public and is, therefore, principally a governmental responsibility. To ensure that this function is effectively performed, governments should establish appropriate policy, legislative and institutional frameworks. Such measures facilitate achieving national objectives on public health and well-being, environmental management and enhancing productivity across various sectors. Although, there is a trend in most countries to move towards management of water resources on a basin or catchment basis following the IWRM approach, water pollution management still lags behind other water resources management functions and has not been fully operationalized and often is not being managed at the same level as water—the basin level.

4.1 INTERNATIONALLY ACCEPTED PRINCIPLES IN WATER POLLUTION MANAGEMENT

There is a number of internationally accepted principles typically found in policy provisions for water pollution management. These include:

1. **Prevention over clean-up.** Because curbing pollution is more logical and cost-effective than cleaning up polluted sites or aquatic ecosystems. Policies and laws to prioritize pollution prevention and reduction approaches—such as minimizing wastewater, in-plant refinement of raw materials and production processes, and recycling of waste products—over end-of-pipe treatment are important.

2. **Precautionary measures.** In cases where the impact of discharging potentially hazardous substances into aquatic environments is unknown, precautionary measures are recommended.

3. **Economic regulation (polluter-pays principle).** Widely recognized and appreciated, the polluter-pays principle places the responsibility for the costs of pollution prevention, control and reduction measures on polluters, aiming to encourage a reduction in environmentally harmful behaviour. For example, industrial wastewater discharges are financially regulated in many countries via policies that use instruments such as permits and sanctions.

4. **Management at lowest appropriate level.** A country's water management policy concerns multiple national agencies and industries and may even have regional implications. At the same time, national policies broadly advocate that pollution prevention and water quality

BOX 4.1 DETERMINING THE APPROPRIATE MANAGEMENT LEVEL

Water quality should be managed at the lowest appropriate level to ensure that decisions and actions are taken as close as possible to affected populations and ecosystems. If, for example, a specific water quality issue only impacts one local community, then pollution management should take place at the community level. If the same issue also affects neighbouring settlements (for example, when the same pollution source causes comparable impacts across several villages sharing the same water resource), management functions must rise a step above the community level—for example, the river basin level.

On a larger scale, the appropriate water pollution management level for major water bodies is often national, particularly in cases where no significant pollution impacts are anticipated for neighbouring states. Further, when several nations suffer significant impacts from the pollution of a shared water body, the problem should be managed on an international level (e.g. by establishing an international river basin commission).

Beyond the geographic spread of pollution impacts, it is important to consider the existing capacity—or the possibility of developing the capacity—to perform water quality management functions at a given administrative level. Existing structures present a clear advantage; for example, if water resources are measured and generally managed at the river basin level, water pollution control and water quality management will be most effectively integrated at this level as well. Other cases are less straightforward; community-level water quality management may require a combination of capacity-building activities and external technical support.

management decisions and actions be taken at the closest possible level to those affected, while higher administrative levels enable lower levels to function in a decentralized manner. Depending on a specific context (i.e. the nature, impact and scale of pollution), appropriate management levels can range from regional and national to basin, village or an aquatic ecosystem that supports multiple communities (see Box 4.1).

5. **Ecosystem-based cross-sectoral integration.** Water pollution management generally takes an ecosystem-centric approach, requiring that water resources management integrate environmental needs alongside other water-related and water-using sectors.

6. **Participation and inclusion.** Water pollution prevention and management requires public consultations and involvement of all key stakeholders, particularly of the communities affected by water pollution.

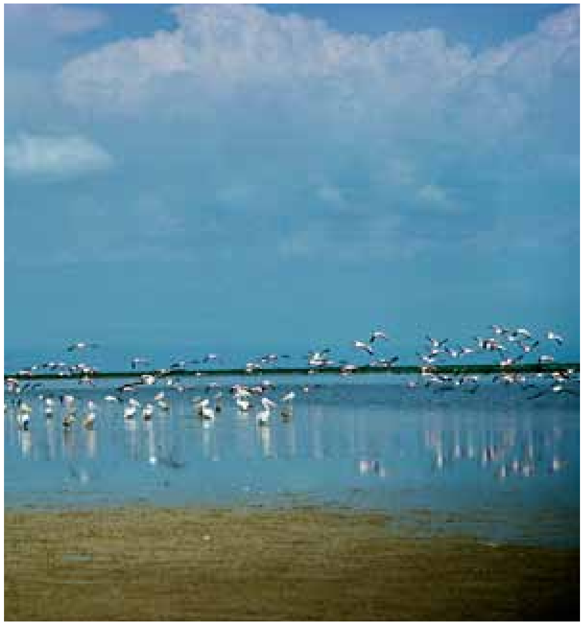
7. **Cooperation on transboundary water quality management.** Riparian states typically cooperate to manage transboundary water-related issues. In most such cases, stakeholder countries establish a body comprised of national representatives to facilitate international cooperation and coordinated implementation of measures in shared waters.

4.2 POLICY AND LEGISLATION FOR POLLUTION MANAGEMENT

4.2.1 Policy framework

Integrating water pollution prevention into national policy translates political intentions into actions that impact water resources management. Such provisions can be part of a country's water resources policy document or of the national environment policy.

Water pollution is a cross-cutting issue that needs mainstreaming into multiple sectoral policies and plans, not just those of a country's water management institution. Most often, it is the environmental and water government agencies that address pollution issues, prevention and management—for example, when establishing national environmental policy or as part of water resources management and planning. Most countries' constitutions refer to water quality in connection with the environment, water resources management or both. In some cases, public health-related policy also addresses water pollution.



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Although the areas of environmental conservation, water resources management and public health interact closely, they are typically administered by different line ministries, making implementation of water quality-related mandates and management functions challenging and often redundant. Over the last 20 years, the advent of IWRM has enabled many countries to improve synergy and collaboration among government agencies addressing water pollution. Other countries continue to strive for greater harmonization and integration.

Integrating water pollution prevention into national policy translates political intentions into actions that impact water resources management. Such provisions can be part of a country's water resources policy document or of the national environment policy. Water pollution management can also be formulated as a standalone policy that facilitates the national agenda in both human health and environmental conservation. The most suitable approach depends on a particular country's existing administrative infrastructure for water resources and environmental management; however, it is critical to embed pollution control and management in broader water resources management.

For example, Uganda's national environmental policy encompasses water quality management and provides direction on water-related aspects of environmental conservation, the mandate of the National Environment Management Authority. Water quality management provisions are also reiterated and operationalized in the national water policy and supporting legislation. The two policies acknowledge the cross-cutting relevance of water resources to multiple sectors, while recognizing that water quality management is part of water resources management and delegating operational functions to the national Directorate of Water Resources Management. The environmental and water agencies coordinate and collaborate to prevent pollution and manage water quality, streamlining resources and functions.

In Kenya, both environmental and water policies address water quality but are managed by two separate government agencies, resulting in duplication of interventions and even occasional conflict. Both the environmental agency and the water resources management authority independently regulate water pollution and collect separate payments for wastewater discharge. Such lack of communication and integration challenges in water pollution management has the potential to erode public trust in the government's ability to adequately address the issue.

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Many strategic and operational inefficiencies can be eliminated by advocating for a coherent national IWRM policy framework that encompasses water quality management, unites all stake-holders in addressing pollution issues and promotes specific coordinated action.

There are also countries that focus on water pollution management only in the context of the national environmental policy and not water resources. In Rwanda, water pollution reduction and management is the mandate of the environmental agency, and the lack of a link to the water resources management agency results in an inability to consider the combination of water quantity and quality to compute pollution loads.

Many strategic and operational inefficiencies can be eliminated by advocating for a coherent national IWRM policy framework that encompasses water quality management, unites all stakeholders in addressing pollution issues and promotes specific coordinated action. Guiding principles for policy advocacy include:

- **Integration:** Water quality management should be seen as part of a coherent policy framework that specifically addresses environmental conservation and water resources management, including the needs of industry, agriculture, urban development and other water-using sectors.
- **Collaboration and coordination:** Joint planning and coordinated implementation among stakeholder government agencies can greatly improve the effectiveness of pollution control measures.
- **Inclusion and consensus-building:** The policymaking process should involve consultations and seek to build consensus among stakeholder agencies.
- **Pragmatism:** Policy provisions must be realistic and applicable in practice.
- **Legislative cycle alignment:** Policy provisions—i.e. the strategies and targets of water pollution control measures—need to remain relevant throughout a long and laborious political adaptation process.

DISCUSSION QUESTION

What is the best way to address the issue of multiple institutions with different mandates on water pollution control?

BOX 4.2 COMPONENTS OF WATER POLLUTION MANAGEMENT LEGISLATION

- Statement of motive and underlying water pollution principles and priorities
- General provisions (terminology used and authorities responsible for implementation of the law)
- Conservation and protection of water resources (ecosystem protection and environmental sustainability; minimum flow requirements)
- Management of water resources (institutional arrangements; actors, mandates and responsibilities; stakeholder rights, obligations and roles)
- Regulation of water resources (industrial wastewater: setting standards, compliance monitoring and enforcement)
- Dispute resolution (e.g. formal legal proceeding, arbitration, mediation)
- Sanctions (powers of regulators and the police, procedures to follow, penalties)
- Transitional and final provisions (existing rights, international cooperation on shared water resources)

4.2.2 Legislative framework

Legislation translates policy into action by enacting laws and regulations. Legislation provides guidance for the framework subsequently elaborated by regulations or other contextually suitable instruments. Water quality legislation in particular exists to:

- Formalize the process of pollution control and water quality management by elaborating key goals, terms, actors and processes (see Box 4.2);
- Clarify the entitlement and responsibilities of polluting actors (e.g. industrial companies responsible for wastewater discharges);
- Clarify the role of the state vis-à-vis other stakeholders in matters of pollution prevention and water quality management;
- Establish legal requirements and standards for polluters to control/prevent discharges and ensure sustainability of water resources.

Water pollution may be addressed as part of national environmental legislation and action plans, within water resources management legislation or in both. No particular institutional arrangement is preferable; however, integration and cooperation of these two types of stakeholders is essential.

Effective and relevant water pollution management legislation exists in some countries, but challenges of inadequate implementation and enforcement persist, typically resulting from insufficient political will, inadequate institutional frameworks, absence of technical capacity, and lack of cooperation and coordination. Similar and sometimes more complicated challenges occur at the international level, where enforcement of International Water Law depends on individual states' implementation of national laws already facing many challenges (see Box 4.3).

DISCUSSION QUESTION

Laws are only effective when they are enforced and strictly monitored to achieve their purpose. Are pollution control laws in your country effective?

BOX 4.3 STREAM RESERVATION AND WATER QUALITY-RELATED LEGISLATION IN SRI LANKA PROVES EFFECTIVE

In Sri Lanka, two recent research studies—on the effectiveness of laws and legislations in preventing encroachment of stream reservations, and on sanitation-related policies and legislations—concluded that the existing regulatory mechanisms comprehensively cover all aspects of water resources management and specifically the protection of stream reservations in Sri Lanka. The large number of institutions created as a result of these regulations have appropriate authority but appear to have largely overlapping mandates. There are also serious deficiencies in the implementation of the regulations. Lack of coordination among the concerned institutions, procedural lapses, political interference, and lacking enthusiasm among state employees to implement rules and regulations have been the primary reasons for institutions' inaction in preventing land encroachments along stream reservations or controlling water pollution resulting from wastewater discharges and solid waste.

4.3 INSTITUTIONAL FRAMEWORK FOR WATER QUALITY MANAGEMENT

4.3.1 Water pollution management functions

Water pollution control and management comprises two complimentary regulatory functions that require specific expertise and supporting institutional arrangements: managing water quality and establishing a licensing and enforcement system to control pollution.

Water quality management entails establishing operational quality standards for receiving water and discharged waste, supported by integrated planning in order to achieve water quality levels that allow resources to meet demand.

Licensing and enforcement involves establishing effluent standards and devising methods to minimize waste and protect water quality. Any licensing instrument, such as a paid wastewater discharge permit system, must address the monitoring and enforcement of its regulations.

In most countries, setting discharge and water quality regulations has proven to be straight-forward and cost-effective, although enforcement of the regulations remains a challenge.

DISCUSSION QUESTION

Does water quality planning and management take place at the basin level in your country?

4.3.2 Institutional structure

The institutional arrangements for water pollution management are entirely contextual. Water quality, its prominence on the national agenda, and the administrative and technical capacity to manage it can vary greatly from one country to another—and with time, as circumstances change. Industrialized countries have the highest levels of political will and the requisite technical and institutional capacity to address water pollution. Such nations have, over time: analysed the health, environmental and economic impacts of water pollution; understood that pollution prevention is not only more logical but also more cost-effective than end-of-pipe solutions; interacted with a variety of pollutants requiring different control methods; and, as a consequence, recognized that water resources are strained by high demand and should be protected and conserved.

The institution tasked with water pollution management handles the regulatory, licensing and enforcement aspects of water pollution. Often, a government department oversees water quality, but this responsibility can also fall to organizations dealing with infrastructure. On the other hand, licensing and enforcement are typically the domain of environment and water ministries, and in some cases of dedicated government agencies, such as the Environmental Protection Agencies in China and USA, the Pollution Control Board in India, and the National Environmental Management Agencies of many African countries.

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Successful implementation of water pollution management functions depends primarily on the suitability of the chosen institutional arrangement and the availability of the required financial, technological and human resources. There is no fixed institutional arrangement model that would suit all countries at all times. Rather, each country needs to identify its water quality priorities and develop the most appropriate institutional structure based on how water resources are managed and the optimal venues for engaging various stakeholders (government agencies, communities, private sector).

In Uganda, water pollution is addressed by a national environmental management policy and legislation and is hence overseen by the National Environment Management Authority as part of its broader environmental management mandate. However, operational functions—such as the practical implementation of the National Water Policy and the Water Act—have been delegated to the Directorate of Water Resources Management. The Directorate has decentralized water resources management functions to separate basins (Water Management Zones), with water pollution control and management integrated into basin-level functions, while the two bodies interact and collaborate.

In contrast, some countries categorize water pollution an environmental issue and, as such, do not address pollution management in national water resources management policy or legislation. In such cases, environmental agencies typically take on water quality management functions, and the institutional structure for water pollution management follows that of environmental management. This presents a number of challenges.

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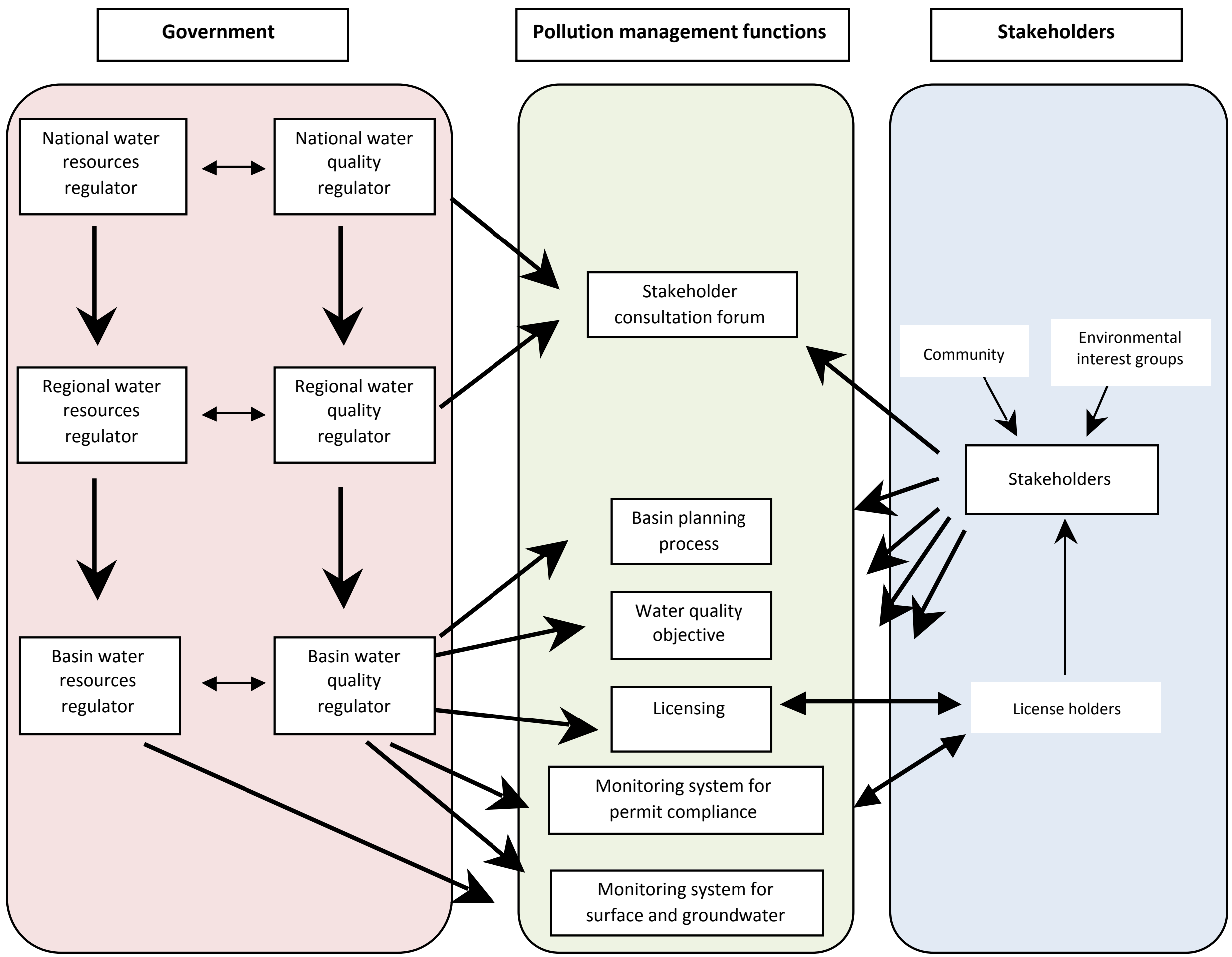
While environmental conservation is among the central goals of water pollution management, it must be closely linked to broader water resources management, as water pollution not only endangers a natural resource but also threatens human health and development. An environmental agency lacks the expertise and authority to assess, mitigate or regulate threats within other sectors; establishing an effective water pollution management system requires a cross-sectoral institutional partnership, even in cases where a single agency takes an operational lead.

In addition, lack of integration often leads to critical operational gaps—for example, in water quality monitoring and regulation. When pollution management and resource allocation are managed by different government bodies, the interdependent variables of water quality and quantity are regulated and monitored separately. Water quality determines its possible uses and, as such, its value and availability for specific uses. Water quantity determines the pollution load that may be acceptable. Consequently, the most appropriate institutional framework for water pollution management is one that has a relationship with water resources management (see Figure 4.1 for a generalized structure).

While environmental conservation is among the central goals of water pollution management, it must be closely linked to broader water resources management, as water pollution not only endangers a natural resource but also threatens human health and development.

In practice, the optimal institutional arrangement for water pollution control and management will depend on a given political and institutional environment, economic policy, the prominence of water quality and environmental conservation on the political agenda, and the role and value of water in the area (district, country or region), among numerous other contextual factors. As demonstrated by some of the preceding examples of different institutional and legislative arrangements, institutional constraints and power relations often present insurmountable barriers to what is obviously good practice.

FIGURE 4.1 GENERALIZED INSTITUTIONAL FRAMEWORK FOR WATER POLLUTION MANAGEMENT



KEY MESSAGES

- Water pollution management is usually addressed in connection with environmental legislation, within the framework of water resources management planning and in public health policy.
- The policy, legislative and institutional framework for water pollution management should follow an IWRM framework in order to promote collaboration and coordination among key stakeholders.
- Most countries manage water quality within administrative and political boundaries, while IWRM principles promote an ecosystem-based approach that corresponds with watershed boundaries.
- Water pollution management is most effective at the lowest appropriate—most often the basin—level, where decisions and actions are taken in close proximity to the relevant stakeholders.
- Water pollution control and management is closely linked to water resources management, because changes in water quality impact useable volume—and changes in volume affect quality. An appropriate institutional network for water quality management is strategically and operationally linked to water resources management.

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LEARNING OBJECTIVES

In this module, participants will learn to:

- **Understand water pollution management policies and strategies;**
- **Apply commonly used guiding principles in water pollution prevention and management;**
- **Identify appropriate management instruments;**
- **Develop a strategic framework for water pollution management; and**
- **Translate strategies into action plans.**

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MODULE 5

Strategic framework for water pollution management

Water pollution is of cross-cutting relevance for practically all sectors, actors, climactic zones, political and institutional structures, legislative systems and economic contexts. On the ground, water pollution prevention and management approaches differ greatly as a consequence of this diversity of settings. However, it is important to underscore the foundational principle: water pollution management is only meaningful and effective when organized within an IWRM framework that jointly considers the interdependent variables of water quantity and quality, and ensures cross-sectoral coordination to prevent pollution and achieve water quality targets.

The structural elements of a water pollution management system include policy, strategy, action plan, and monitoring and evaluation measures (see Table 5.1). The remainder of this module provides guidance on adapting this structural framework to varied contexts and discusses approaches that can improve the overall coherence of water pollution management.

TABLE 5.1 ELEMENTS OF A WATER POLLUTION MANAGEMENT SYSTEM

ELEMENT	DESCRIPTION
Policy	A policy is a set of political decisions about resource entitlements and responsibilities (who receives/does what, when and how). A water quality or pollution prevention policy establishes the principles that govern setting goals for water quality, emissions permits, management arrangements, and the roles and responsibilities of involved institutions and stakeholders. Founded on the guiding principles for water quality management, a policy is shaped by a nation's development goals, socio-economic context and degree of conflicting demands.
Strategy	A strategy sets out the process and broad lines of action needed to move from the present situation to point a desirable future situation. The strategy includes a diagnostic analysis of the current situation, while future conditions are defined through a participatory stakeholder process. The strategy is further informed by existing policy and supporting legislation, the institutional environment and an analysis of potential outcomes, lessons learned and the feasibility of achieving specific goals in a given context. The strategy broadly outlines the actions stakeholders identify as necessary to facilitate achieving set goals in a given period of time and provides a rough estimate of resource requirements. Several distinct strategies may focus on achieving the same goal using different approaches.
Action plan	An action plan provides details of the process and activities, including project tasks and timing, coherence, cost and other resource requirements. In addition, an action plan typically defines the assumptions and indicators for measuring progress and confirming that activity-specific outputs and objectives have been achieved.
Monitoring and evaluation measures	Ongoing monitoring of agreed indicators takes place at appropriate intervals. Indicator values are analysed to evaluate whether existing strategies and plans require adjustment to reach set goals.

5.1 STRATEGY DEVELOPMENT

5.1.1 IWRM change areas and guiding principles

Prior modules have elaborated the basis for strategy development by identifying the change areas and guiding principles for water pollution control and management.

A strategy's effectiveness is a function of policy, institutional and management support (see Box 5.1 and Module 2). All efforts and interventions under a water quality management strategy aim to attain change in one of these areas. Examples of such changes include

BOX 5.1 CHANGE AREAS FOR WATER POLLUTION MANAGEMENT

- **Enabling environment:** policies, legislation and regulations that align with the water resources management and govern all related stakeholder action towards water pollution control, prevention and achieving good water quality
- **Institutional framework:** an operational arrangement that allows for integrated implementation of water pollution management functions across various administrative sectors and levels
- **Management instruments:** tools and systems that facilitate decision-making, planning, implementing and monitoring water quality management functions

BOX 5.2 GUIDING PRINCIPLES FOR WATER POLLUTION MANAGEMENT

- Prevent pollution rather than treat its symptoms
- Utilize precautionary measures to mitigate potential impact
- Balance economic (polluter-pays measures) and regulatory instruments
- Manage water pollution at the lowest appropriate level (typically the basin level)
- Set realistic benchmarks with water quality standards and regulations
- Advocate for water pollution control, encourage public dialogue and provide open access to information
- Establish mechanisms to promote and facilitate participation and ensure inclusion
- Prioritize stakeholder consensus-building
- Aim for ecosystem-based cross-sectoral integration, collaboration, coordination and transboundary cooperation in water pollution management
- Adapt water pollution management strategies to the local economic, political, institutional and legislative context

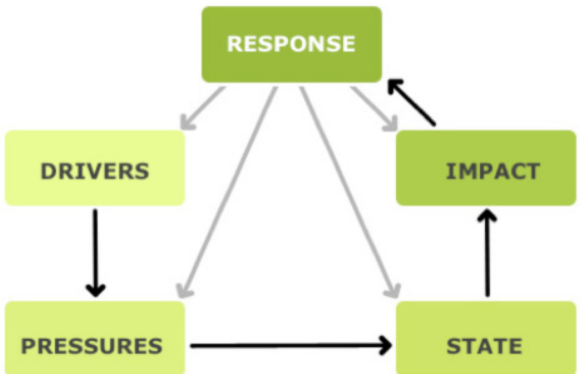
passing new wastewater discharge legislation, harmonizing various government bodies' water quality-related roles and responsibilities, or devising efficient information systems (e.g. for progress monitoring, stakeholder communications). The strategy must provide water quality managers with sufficient guidance to realize stated objectives, from general direction to practical guidance and adequate detail to help identify and formulate concrete actions and projects.

Analysis of water pollution management efforts in a number of countries has yielded a set of internationally accepted guiding principles (see Box 5.2 and Module 4). It is also important consider the lessons learned and best practices of specific projects, as IWRM case studies from similar political, economic or geographic contexts may help identify particularly applicable strategies and tools.

5.1.2 Analytical approach: DPSIR model

The environmental sector has devised multiple tools to help practitioners understand the causal chain of interactions between human endeavour and the environment. One such tool—the Driving forces, Pressures, States, Impacts and Responses (DPSIR) model for environment-society interactions—is particularly useful in analysing water quality management needs.

FIGURE 5.1 DPSIR MODEL OF INTERACTIONS BETWEEN THE ENVIRONMENT AND SOCIETY



Source: EEA 2007.

The DPSIR model can encourage and support decision-making by pointing to clear steps in the causal chain where it can be broken by policy action. The DPSIR provides a full system view, where social and economic development exerts pressure on the environment and, as a consequence, the state of the environment changes. In turn, this leads to impacts on, for example, human health, ecosystems and materials, and may elicit a societal response that affects the original driving forces, pressures, state or impacts through adaptation or curative action (see Figure 5.1).[41]

Applying the DPSIR model to water pollution management develops practitioner understanding of the scope and nature of water pollution in a given local, national or regional context (see Table 5.2). Identifying distinct water quality levels and pollution issues and quantifying and qualifying their impacts underpins categorizing and prioritizing needed actions, while evaluating existing management capacity clearly defines human and financial resource needs. The Response portion of DPSIR analysis broadly outlines a water pollution management strategy, subsequently translated into an action plan that details institutional and project implementation arrangements, tasks, schedules, monitoring activities and financing requirements.

The majority of water quality-related interventions and management tasks are most effective when implemented at the basin level, within an area defined by an aquatic body's boundaries and dependent ecosystems. Water pollution management strategies unite multiple water sources and bodies under a common conceptual agenda and customize actions based on the unique drivers and pressures of each area. The DPSIR analytical model is equally applicable at district, national and regional levels—any level that facilitates the broad cross-sectoral integration central to IWRM.

41 EEA 2007.

The DPSIR model can encourage and support decision-making by pointing to clear steps in the causal chain where it can be broken by policy action.

TABLE 5.2 APPLYING DPSIR MODEL TO WATER POLLUTION MANAGEMENT STRATEGY DEVELOPMENT

DPSIR MODEL	WATER POLLUTION MANAGEMENT
Driving forces	Population growth, economic (industrial and agricultural) development, urbanization, climate change and ecologically significant natural changes (see Module 1)
Pressures	Water pollution from point and non-point sources (see Module 1)
State	■ Identification of water quality and pollution issues (i.e. problems that the water pollution management systems will be able to deal with) ■ Analysis of present capacity and capability (human, logistic and financial resources available for water pollution management)
Impact	■ Categorizing water pollution issues (are they national/local, impact issues or demand issues, risk in terms of Impact x Probability of occurrence) ■ Prioritizing water quality issues (work together with key stakeholders)
Response	■ Identification of required management interventions (what should be done at the management level to address water pollution issues) ■ Identification of long-term objectives (the vision of the future water pollution management system comprising an enabling environment, an institutional framework and required management instruments) ■ Identification of realistic short-term objectives (the first and most efficient steps towards achieving and maintaining desired water quality, and steps to address specific areas of urgent need)

5.1.3 Contextualizing driving forces and pressures on water quality

Module 1 details the scope and impact of water pollution on the global scale, providing a foundation for a comparable analysis of the local situation. The first step of developing a water quality management strategy is analysing the local driving forces—population growth, economic (industrial and agricultural) development, urbanization, climate change and ecologically significant natural changes—that result in the environmental pressures of point-source and non-point pollution.

Varied socio-economic characteristics of different locales result in vastly different sets of central drivers and pressures on water resources. For instance, in urban areas, water quality deterioration can often be linked to sanitation and industry, while nutrient leaching, severe weather events and agricultural waste can have higher relevance for catchment landscapes. Each situation requires a contextually driven strategic approach.

Social mapping and detailed surveys through structured interviews with the affected stakeholders and relevant institutional representatives need to be conducted to identify pollutant sources. Sources and intensity of pollution must be mapped, because strategic interventions and technical solutions will depend on such variables.

5.1.4 Assessing the state (quality and quantity) of water resources

IDENTIFYING, CATEGORIZING AND PRIORITIZING WATER POLLUTION ISSUES

A water resources assessment is a cross-sectoral exercise that establishes the practical basis for water pollution management by analysing water quality records and pollution sources and patterns alongside and as part of broader water resources management.

The next step is a water resources assessment—a cross-sectoral exercise that establishes the practical basis for water pollution management by analysing water quality records and pollution sources and patterns alongside and as part of broader water resources management. The purpose of this assessment is to identify the occurrence (in space and time) of both surface and groundwater, estimate overall and usable quantities and their water quality, and review recent trends in water requirements and water resources development. This assessment does not aim to resolve such issues—only to identify and group them by priority areas for further investigation.

Different issues require equally different management instruments and interventions. For example, water pollution problems at the national level typically require imposing general effluent standards, regulations or other such broad governance measures. In contrast, water pollution affecting a small geographic area may only require passing a local bylaw, establishing a system of dispute mediation or devising a simple technical solution.

BOX 5.3 SETTING PRIORITIES BASED ON BROAD CROSS-SECTORAL CRITERIA

The uncontrolled proliferation of the water hyacinth, *Eichhornia*, in some water bodies will lead to a deterioration in water quality—for example, due to oxygen depletion caused by the decay of dead plants—and may also threaten fisheries, navigation and transport, causing considerable economic consequences. Thus, based on this simple analysis, combating the proliferation of water hyacinth should be given a higher priority than might be indicated by purely environmental considerations.

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It is useful to categorize water quality problems as either *impact* or *user-requirement* issues. Impact issues result from human activities that negatively affect water quality and cause environmental or ecosystem degradation. User-requirement issues are those that derive from an inadequate match between demand (water quality requirements) and supply (actual quality of available water resources). Both types of issues require institutional intervention by actors with the authority to bring about change.

Most initial water resources assessments find that the financial, human and other resources needed to address the full scope of identified water quality issues significantly exceed the resources allocated to water quality management. Therefore, it is important to prioritize issues in order to direct the available resources to addressing the most urgent and significant problems, which should be identified by the law-making authorities in consultation with researchers and scientists.

Prioritizing should favour prevention over clean-up and cross-sectoral interventions. For example, in most cases of ongoing point-source pollution, it is more costly and less effective to purify drinking water then to address—prevent or control—the upstream pollution, attaining the desired water quality and eliminating the need for further treatment. The proliferation of the water hyacinth offers an example of a broad-scope water pollution problem that threatens numerous water bodies and related economic sectors, emerging as a top priority among affected areas (see Box 5.3). Ultimately, prioritizing objectives and interventions requires political will and authority over environmental and socio-economic spheres of activity.

Types of water pollution impacts to be considered include:

- Economic and financial impacts;
- Human health impacts;
- Impacts on ecosystems; and
- Impacts on water resources availability for different uses.

Economic impact valuation can help contextualize the costs of water pollution management by quantifying the losses of revenue resulting from water pollution, the healthcare costs of combating waterborne disease and water purification costs. Such economic assessments could demonstrate the importance of pollution control and management at the policymaking level, helping raise water pollution management up on the national agenda.

These impacts are further affected, often in exacerbating and negative ways, by **risk factors** such as:

- Geographic extent;
- Duration (and intensity, in cases where impacts diminish or exacerbate over time);
- Frequency and probability of occurrence; and
- Vulnerability and resilience of affected communities, water bodies and dependent economic sectors.

A particular water quality problem—for example, caused by wastewater discharge—can have a localized impact in an area of a few hundred metres along a river, or impacts can extend throughout an entire river system downstream of the discharge. Some of the factors affecting the geographic extent of impact include the volume of wastewater, the duration of its retention in receiving water bodies, the water body's own volume of water, the degradability of each pollutant, and the presence of sensitive ecosystems or species in the receiving water body.


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Duration can also vary greatly. A discharge of easily degradable organic material often causes a considerable deterioration of water quality for the duration of the discharge but disappears when the discharge ceases. In contrast, persistent pollutants bio-accumulate in the aquatic environment and have long-lasting post-discharge effects.

Frequent incidence and high probability of repeat occurrence greatly exacerbate impacts. Situations of ongoing point-source pollution resulting from industry and agriculture are among the top threats to water quality. Effective solutions must not only address the current situation—

BOX 5.4. ENSURING GROUNDWATER POLLUTION IS NOT NEGLECTED

Pollution management is often focused on surface water. However, groundwater is just as important, as it feeds overall water resources and numerous drinking water bodies. Discharge regulation and measures that prevent non-point source pollution on land are equally needed to protect groundwater, as practically any surface activity can have an effect on the quality of underground water.

Managing groundwater quality is extremely challenging due to the amount of unknown factors and the difficulty of sampling, monitoring and extrapolating water quality indicators. Because it is out of sight, prior or ongoing damage to groundwater is not always apparent, while clean-up is expensive and may take thousands of years.

Groundwater pollution risk is derived by estimating the potential pollution load and groundwater vulnerability, derived from the natural characteristics of the strata. Risk areas for groundwater pollution are determined by mapping vulnerable areas together with potential contaminant load discharge locations, compiled using records of industrial and mining activities, urban development, waste disposal sites and agricultural fields—all locally relevant sources of point-source pollution.

Groundwater quality management requires measures such as:

- **Identifying point-source and other groundwater threats by both persistent (un-degradable) and degradable pollutants in the basin;**
- **Classifying groundwater by vulnerability and defining source protection zones; and**
- **Ensuring that groundwater quality considerations are integrated into broader water quality and water resources management plans and strategies by devising groundwater-specific policies and strategies to control or mitigate polluting activities.**

water quality as a result of multiple prior discharges—but also anticipate inevitable future impacts and establish sustainable systems of response. Environmental impact assessments are of great help in understanding potential negative impacts on the environment. Many countries and large projects use such assessments to forecast threats to water resources; however, decision makers often overlook the results due to political priorities.

Further, water pollution impacts on aquatic environments and dependent sectors vary based on their individual vulnerability and resilience. For example, an existing municipal water filtration system may adequately mitigate the impact of upstream pollution on the urban population, while small communities using the same water source may see negative impacts on resident health, creating a situation where the same source of pollution poses very different levels of threat to two groups of local inhabitants. Vulnerability and resilience are equally important considerations from an ecological perspective, as aquatic habitats are not equally susceptible to all pollutants.

Finally, pollution management planning begins with a participatory mapping of water quality. This exercise should provide baseline information on a given water body or system and yield an inventory and details of identified point and non-point pollution sources.

DISCUSSION QUESTIONS

Do your national programmes address groundwater quality? How?

Does your country have water quality and pollution source maps or detailed assessments? How could these help to control and manage pollution?

ANALYSING EXISTING MANAGEMENT CAPACITY AND CAPABILITY

The present management capacity and capability need to be identified and analysed as strengths and weaknesses, opportunities and potentials. Aspects such as suitability of institutional framework, number of capable staff, knowledge sources, and availability of financial resources should be considered. The needs for training of staff and for human resources development to enhance management performance should also be identified. Increased cooperation among universities, research centres and water-managing institutions is critical to the effective use of a country's available resources.

5.1.5 Structuring response

Every water quality issue or group of closely related issues identified as needing action will need distinct management intervention.

IDENTIFYING REQUIRED MANAGEMENT INTERVENTIONS

Because contexts differ greatly, it is difficult to provide a road map for matching various water quality issues with different intervention types or defining their scope and length of engagement. Some challenges can only be overcome by years of lobbying for, developing and ultimately passing new legislation, while others may have practical short-term solutions via on-the-ground project implementation.


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Every water quality issue or group of closely related issues identified as needing action will need distinct management intervention. Typically, the nature of the issue will suggest several possible intervention methods; for example, curbing point-source pollution can be approached from a policy perspective (by passing and enforcing new regulations), with negotiation (by establishing cooperative arrangements between polluters and affected communities and working to build self-regulating schemes), or in multiple other ways. Such intervention options should be evaluated for appropriateness to a given water quality problem—that is, the feasibility of a given intervention securing support and funding, being implemented in practice, and ultimately succeeding in addressing the problem. The administrative levels and entities involved in implementing interventions should also be considered as part of this evaluation.

Broadly, types of required management interventions typically include, by IWRM change area:

- **Enabling environment**
  - Identifying key political and institutional stakeholders
  - Advocating to raise priority of water quality management on political agenda
  - Policymaking and planning
  - Preparation and revision of legislation and regulations
- **Institutional framework**
  - Establishing mechanisms for cross-sectoral coordination
  - Devising suitable operational arrangements to facilitate decision-making, management and implementation activities
  - Delineating the roles and responsibilities of institutional partners

UN PHOTO/CAHAIL

- **Management instruments**
  - Estimating non-point pollution contribution
  - Establishing or reviewing systems for:
    - » Water quality monitoring
    - » Issuing discharge permits
    - » Discharge monitoring
    - » Cooperation with polluters
    - » Stakeholder consultation
    - » Mediation of disputes
  - Enforcing regulations
  - Training and capacity-building of stakeholders
  - Information dissemination and advocacy

In many countries, no comprehensive or coherent policy or legislation exist for either water quality management or environmental conservation. This should not preclude endeavouring to manage water quality in general or to address specific water pollution situations that require urgent attention. However, to ensure that even these early efforts contribute to long-term efficiency, it is essential to ground all water pollution management activities and interventions in IWRM principles.

SETTING LONG-TERM OBJECTIVES FOR WATER POLLUTION MANAGEMENT

Long-term objectives for water pollution management envision an efficient system that comprises policy, institutional and management components to integrate IWRM guiding principles (see Box 5.2) with national development goals.

Not every guiding principle is equally relevant to a specific national context; for example, trans-boundary cooperation on water resources management is not a high development priority for landlocked states. In contrast, efficiency requires all long-term plans to prioritize water pollution prevention over clean-up, even in cases where short-term actions must focus on rectifying existing damage, such as post-disaster action to address saltwater intrusion or disrupted sanitation services.

Institutional considerations are a critical component of long-term analysis. A long-term water quality management policy delineates functions to be performed at each administrative level, ensuring to account for the key management processes of decision-making, planning, implementation, monitoring and ongoing operational tasks. Such analysis should be driven by the scope of required work and endeavour to be realistic without focusing on existing administrative and management capacity.

A vision of the future must also acknowledge and address constraints that have the potential to influence a country's ability to achieve long-term water pollution management objectives. Long-term strategic plans should encompass interventions designed to overcome such barriers; for example, solutions to lacking administrative capacity can include capacity-building training and information dissemination, partnerships with community or non-governmental organizations, establishment of a new water pollution management secretariat or organization, and adaption of—or integration of new human resources into—an existing water resources management mechanism or government agency.

DEVELOPING SHORT-TERM STRATEGY FOR IMMEDIATE ACTION

A short-term strategy blends meeting urgent needs with taking the most pragmatic first steps towards achieving long-term water pollution management objectives.

Conducted to provide a starting point for strategy development, the water resources quality and quantity assessment and the subsequent categorizing and prioritizing exercise yield a set of top priorities. Immediate action typically aims to combat the most significant health, economic or environmental impacts of water pollution, and to build resilience and reduce vulnerability to near-future impacts (for example, predictable point-source pollution, extreme weather events in areas of their high probability and other forecast threats to water quality).

Immediate action typically aims to combat the most significant health, economic or environmental impacts of water pollution, and to build resilience and reduce vulnerability to near-future impacts.

Lacking capacities often constrain short-term planning, and activities must be designed to bridge capacity gaps.

In addition to financial resources, short-term actions—and, therefore, objectives—are critically dependent on existing analytical, administrative and implementation capacity. Cases of considerable top-level capacity, such as the existence of a national water resources management body with an expressed commitment to water quality, can facilitate expedient action on policy and regulation by providing access to established systems and processes. Such synergies become apparent when comparing the outputs of water quality and capacity to manage, providing opportunities for efficient short-term action towards long-term goals.

In contrast, lacking capacities often constrain short-term planning, and activities must be designed to bridge capacity gaps. For example, a long-term objective might be to decentralize water quality monitoring activities but existing manpower, skills and analytical capabilities of lower administrative levels may not allow short-term decentralization. The short-term solution may be to maintain national monitoring activities and concurrently improve community and basin-level capacities through training activities and orientation programmes. Alternatively, the scope of basin-level monitoring can be restricted to limit the required skill, allowing for some decentralized monitoring activities to begin immediately while phasing in additional human resources and capacity-building activities over time.

Finally, conducting ongoing and outcome evaluations and documenting best practices and lessons learned is essential to inform future planning. Periodic monitoring of achievements against indicators allows for in-progress course adjustments not only on an individual project scale, but also at the national level. As initial long-term strategy development is often a theoretical exercise, it is critical to periodically review national water quality management goals, objectives and interventions to ensure they remain relevant in view of field-level data and information.

5.2 MANAGEMENT TOOLS TO CONTROL POLLUTION

POLICY INSTRUMENTS

- **Regulations** are detailed rules stemming from legislation.
- **By-laws** are subordinate to regulations and are binding for defined local areas.
- **Management procedures** are sets of guidelines and codes of good practice that ensure consistent problem-solving and decision-making.

(See Module 4.)

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WATER QUALITY STANDARDS

Objectives (standards) for ambient water quality are commonly set according to the intended use of water (e.g. drinking, fishing, spawning), while effluent standards are based on either or both:

- **Fixed emission standards** that require a certain level of treatment of all wastewater, regardless of the conditions and intended use of the receiving water body; and
- **Environmental quality standards** that define the requirements to effluents in compliance with the quality objectives for the receiving water body.

(See Module 6.)

ECONOMIC INSTRUMENTS

- **Resource pricing**
- **Effluent charges**
- **Product (green) charges**
- **Subsidies**
- **Non-compliance fines**

(See Module 7.)

MONITORING SYSTEMS

Monitoring provides information for decision-making. Monitoring of point sources and the ambient environment establishes levels, trends and variations in chemical and biological parameters, and total pollution loads. Monitoring will among others, establish the impact of treatment and pollution reduction and be part of the decision basis for further interventions. (See Module 10.)

WATER QUALITY MODELLING


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Modelling activities expand knowledge, range in complexity and can include:

- **Pollution load determination**
- **Evaluation of effects and impacts**
- **Mathematical mass balance simulation models**
- **Advanced ecological simulation models**

Technical knowledge on mapping and modelling needs to be acquired with the help of local and regional universities, where capacity development could play a key role.

ENVIRONMENTAL IMPACT ASSESSMENTS

This key instrument measures the anticipated effects of specific development programmes and projects (see Module 3).

In order to voice opinions and otherwise contribute, stakeholders need to understand the importance of water quality and the issues and approaches that managing it entails.

AWARENESS-RAISING AND EDUCATION

Advocacy and information-sharing are often prerequisites for stakeholder cooperation. In order to voice opinions and otherwise contribute, stakeholders need to understand the importance of water quality and the issues and approaches that managing it entails. Various stakeholder types—e.g. affected communities, environmental activists, politicians, policymakers, polluters—have different needs and threats and require targeted communications approaches. Communications methods can range greatly and can involve the media, local organizations, extension officers, and knowledge-sharing platforms and products ranging from websites to flyers, brochures and other publications.

Importantly, capacity development needs for awareness-raising and education should be identified through needs assessments, which can take the form of simple social surveys. Understanding of knowledge management practices is very important when planning capacity development focusing on making a change. Information on water quality and pollution should be incorporated in a country's education curriculum. Social media is an effective method for raising awareness, but training is required by various stakeholder groups to make progress and raise water pollution management up on the national agenda.

DISCUSSION QUESTIONS

Why does water pollution management have such a low priority in many countries?
How should capacity be developed to design and operationalize a water pollution management system?

A holistic approach to a strategic framework for pollution management defines overall strategic objectives and strategies, and addresses the existing conditions, future conditions, future targets, improvement estimates, management tools and implementation plans—in a cyclical manner (see Figure 3.5 on page 45).

KEY MESSAGES

- Water pollution management is only meaningful and effective when organized within an IWRM framework that jointly considers the interdependent variables of water quantity and quality, and ensures cross-sectoral coordination to prevent pollution and achieve water quality targets.
- Long-term objectives for water pollution management envision an efficient system that comprises policy, institutional and management components to integrate IWRM guiding principles with national development goals.Institutional considerations are a critical component of long-term analysis.
- In the short term, is important to prioritize issues in order to direct the available resources to addressing the most urgent and significant problems. Prioritizing should favour prevention over clean-up and cross-sectoral interventions.
- Water pollution impacts include economic and financial impacts, human health impacts, impacts on ecosystems and impacts on water resources availability for different uses.
- Management tools to control pollution include policy instruments, water quality standards, monitoring systems, water quality modelling, environmental impact assessments, and awareness-raising and education.
- A strategic water pollution management framework should be designed with a holistic perspective, from contextualizing the driving forces to identifying, categorizing and prioritizing water quality issues, setting objectives and identifying required management interventions. Management tools for pollution control should be integrated in a country's legislative, political, social, economic, technical and institutional spheres of activity.

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GROUP EXERCISE

Risk mapping with Water Resources Issues Assessment Matrix

Note: This exercise also introduces Module 6.

Purpose: To classify pollution risks in a catchment by occurrence risk and impact gravity using the WRIAM method.

Time: 90 minutes

Instructions

When preparing IWRM strategies, roadmaps and plans, it is of paramount importance to ensure that the most important and significant water resources-related issues are identified, ranked and addressed rationally and comprehensively. Comparing the severity of different issues often becomes a case of the proverbial apples and oranges. Although such a comparison is theoretically impossible, a ranking method is required to avoid a confusing and non-operational arrangement based on subjective opinions.

The Water Resources Issues Assessment Matrix (WRIAM) is a consistent ranking method that can be applied over a large range of water resources-related issues. WRIAM ranking uses five criteria, including:

- A1: Importance of condition (graduated from local to international scale);
- A2: Magnitude of degradation (graduated from no change to major disadvantage);
- B1: Permanence (graduated from no change to permanent);
- B2: Reversibility (graduated from no change to irreversible); and
- B3: Additivity (graduated from light cumulative to strong cumulative character).

In this exercise, ranking of the issues is discussed and collectively agreed upon. The issues can be those of quantity or quality, surface water or groundwater, impact or demand, resource mobilization or risk. The scores are combined to yield an overall score and a range (ranking) value. The operations have been programmed into the WRIAM matrix (an Excel sheet), and the resulting values can be compared directly to provide an indication of priority issues and methods of addressing them.

In practical terms, this exercise could be started by grouping participants according to nationality or river basin. Each group then identifies issues of relevance to the country or river basin, discusses and ranks such issues using the WRIAM matrix and ends the exercise by discussing the usefulness of the WRIAM approach.

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PART III

Pollution management interventions

LEARNING OBJECTIVES

In this module, participants will learn to:

- **Assess the status (risk of hazards) of water bodies;**
- **Understand the basis for setting water quality guidelines and objectives and effluent quality standard;**
- **Appreciate the importance of classifying water bodies to establishing water quality objectives; and**
- **Identify strategies and approaches to narrow the gap between existing water quality and desired quality standards.**

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MODULE 6

Water quality management: guidelines, objectives and standards

Most of our water bodies are polluted, and improving water quality requires so many actions that a practitioner may have difficulty deciding where to start and how to proceed progressively. This module helps water managers facilitate agreement on desirable water quality levels and effluent standards, identify risks and pollution sources, and set water quality management objectives. Setting water quality criteria and levels is a scientific task; although water quality standards exist for various water uses, establishing water quality objectives is rather a political process that should be treated as a national priority. An understanding of the context is essential to understanding the extent of the water pollution issue to be addressed; this module covers assessing water pollution risks, identifying point and non-point pollution sources, and setting water quality guidelines and objectives.

6.1 WATER POLLUTION RISK ASSESSMENT

Pollution risk assessment is a tool that helps identify targets by recognizing hazards (see Box 6.1), assessing their severity and prioritizing them to inform the strategy for tackling them. Risks associated with each hazard are qualified and quantified by its likelihood of occurrence and severity of impacts on public health, aquatic life and ecosystems, with a distinction between human health and that of other species (see Box 6.2).

Most methods of risk assessment consider both vulnerability (of a water source and associated ecosystems) and pollutant loads (introduced by a hazardous event), as it is possible for highly vulnerable water bodies to have no pollution risk in the absence of significant contaminant

BOX 6.1 HAZARDS AND HAZARDOUS EVENTS

Hazards are the physical, biological, chemical or radiological agents whose presence in water bodies can cause harm to public health, aquatic life and ecosystem services.

Hazardous events introduce hazards into aquatic environments; for example, excessive use of fertilizers in farming (hazardous event) often leads to increased nitrogen and phosphate levels (hazards) in water bodies.

BOX 6.2 ASSESSING HEALTH HAZARDS AND IMPACTS

Health hazards and impacts cause deviations from health targets. A maximum permissible level of contaminants is widely used as a reference for identifying health hazards; such levels are usually based on scientifically derived acceptable levels of toxicity to either humans or aquatic organisms.

In contrast to humans, health targets for aquatic life are more difficult to set, because aquatic ecosystems vary enormously in composition both spatially and temporally. In addition, acceptable toxicity levels for aquatic organisms tend to be lower than for humans. As such, setting health targets for water quality on a human centred basis fails to account for other species dependent on aquatic ecosystems and may even have adverse impacts.

The quality of water required to maintain ecosystem health is largely a function of contextual natural conditions. Some aquatic ecosystems are able to resist large changes in water quality without any detectable effects on ecosystem composition and function, whereas elsewhere, sensitivity to very small changes in the physical and chemical make-up of the water body can lead to degradation of ecosystem services and loss of biodiversity. Recovery capacity varies as well; some ecosystems can recover or adapt to water quality changes over a period of time, but many ecosystems cannot. Assessing and monitoring the diversity and abundance of dependent organisms in an ecosystem is important part of risk assessment.

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loads—and vice versa. Risk assessments should aim for specificity, adapting a quantitative or semi-quantitative approach that balances estimates of hazard likelihood and frequency with severity of consequences.

6.1.1 Quantitative risk assessment

There are multiple quantitative methodologies for assessing the vulnerability of water sources. For example, the DRASTIC[42] and WRASTIC[43] indices allow assigning numerical values to risks of surface water and groundwater contamination, respectively. Each index combines several rated and weighed parameters (see Table 6.1) to generate a vulnerability rating. The higher the rating, the more sensitive the water is to contamination.

TABLE 6.1 DRASTIC AND WRASTIC INDICES: PARAMETERS INFLUENCING WATER VULNERABILITY

WRASTIC INDEX (SURFACE WATER)		DRASTIC INDEX (GROUNDWATER)	
W	Wastewater discharges	D	Depth to water table
R	Recreational land use impacts	R	net Recharge of water to aquifer
A	Agricultural land use impacts	A	Aquifer media
S	Size of watershed	S	Soil media
T	Transportations avenues	T	Topography
I	Industrial land use impacts	I	Impact of vadose zone
C	vegetative Cover	C	hydraulic Conductivity

Note to the facilitator: The facilitator requires an in-depth understanding of the DRASTIC and WRASTIC methodologies; please see the Resources and Bibliography Section at the end of this module.

42 Aller et al. 1987.

43 US State of New Mexico 2000.

6.1.2 Semi-quantitative risk assessment

Risk assessments aim to distinguish between significant and less significant risks. Often, a semi-quantitative approach that is less complex than working with existing indices can be a contextually appropriate and realistic approach to assessing risks. Table 6.2 presents a matrix that ranks hazard frequency and impact severity on a scale of 1 to 5 each, and the interaction (multiplication) of the two variables yields an overall hazard risk ranking of 1 to 25, where higher numbers represent higher risk.

TABLE 6.2 RISK ASSESSMENT MATRIX BY HAZARD LIKELIHOOD AND IMPACT

RISK RATING BY HAZARD LIKELIHOOD AND FREQUENCY	RISK RATING BY IMPACT SEVERITY				
	INSIGNIFICANT OR NO IMPACT (1)	MINOR IMPACT (2)	MODERATE IMPACT (3)	MAJOR IMPACT (4)	CATASTROPHIC IMPACT (5)
Almost certain – daily (5)	5	10	15	20	25
Likely – weekly (4)	4	8	12	16	20
Moderate – monthly (3)	3	6	9	12	15
Unlikely – annually (2)	2	4	6	8	10
Rare – once every 5 years or less often (1)	1	2	3	4	5
Risk rating	<6 low	6–10 medium	10–15 high	>15 very high	

Table 6.3 provides broad-scope examples of rating the risk of some manmade hazards, and natural disasters should be examined alongside these as potentially major sources of water pollution. All potential hazardous events and associated hazards should be systematically identified and scored, noting that the same event may have different risks in different parts of a water system, as the vulnerability of people and ecosystems may vary based on a given context (e.g. between densely populated and unpopulated areas).

The same event may have different risks in different parts of a water system, as the vulnerability of people and ecosystems may vary based on a given context (e.g. between densely populated and unpopulated areas).

TABLE 6.3 EXAMPLE OF RISK ASSESSMENT FOR POSSIBLE HAZARDS

HAZARDOUS EVENTS	TYPE OF HAZARD	LIKELIHOOD	SEVERITY	RISK RATING	BASIS
Leaking sewer	Microbial	5 (daily)	5 (catastrophic public and environmental health impacts)	25 (very high)	Potential illnesses caused by pathogens, harm to ecosystems and industry (fish/fisheries) and loss of recreational water uses.
Pesticide use in farm lands	Chemical	2 (annually)	4 (major regulatory impact)	8 (medium)	Toxic chemicals can lead to concentrations above water quality guidelines.
Mine waste storage dam breach	Chemical	1 (rarely, once in 5-10 years)	5 (catastrophic public and environmental health impacts)	5 (low)	Chemical waste can cause disruption of all downstream water uses, potential illnesses and environmental damage.


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Judging a hazard's likelihood or impact severity requires local experience and knowledge. One of the critical challenges in risk assessment is insufficient information and stakeholder engagement. Cases of absent or inadequate data should err on the side of caution, leaning towards higher risk rankings. It is critically important to engage an inclusive selection of various stakeholders in risk assessment processes, as individuals' and groups' views of impact severity and hazard likelihood may vary considerably.

6.1.3 Post-assessment actions

All hazards assessed as high or very high risk require immediate attention to risk reduction and contingency planning. Hazards classified as moderate or low risk should be documented and regularly monitored. High scores in either frequency or severity may also pose serious risks; for example, while it is not possible to predict when a mining waste storage facility may have a pollution-causing accident, it is wise to establish risk reduction and contingency measures as soon as possible, given the potentially catastrophic consequences of such an accident to human and aquatic life.

Risk assessment must be ongoing, as hazards and the risks they pose change over time. Some risks may diminish naturally or with concerted action, but new hazards are bound to arise. New actors may become involved in water pollution management work, and new or different information may become available. As such, pollution risk assessment must be an element of IWRM at the river basin level—periodically updated and subject to the input of and acceptance by all concerned stakeholders. A water pollution risk assessment map can be prepared and circulated among river basin stakeholders to inform priority-setting and preparing an action plan. Mapping can range from simply drawing a map to using geographic information system software, depending on the capacity of the responsible institution and individuals. Risk mapping facilitates information-sharing among stakeholders and taking action to lower the identified risks.

DISCUSSION QUESTION

Does your country use a risk assessment process as a means of prioritizing action?

6.2 WATER QUALITY GUIDELINES AND OBJECTIVES

Necessary to protect existing and potential beneficial water uses, water quality guidelines and objectives form the basis of pollution control regulations and the specific measures of prevention, control or reduction of water pollution and other adverse impacts on aquatic ecosystems.

Water quality guidelines and objectives describe—quantify and qualify—the desired or intended quality levels of a water body or group thereof, defining the ultimate goals of the overall water quality status and pollution management. Necessary to protect existing and potential beneficial water uses, water quality guidelines and objectives form the basis of pollution control regulations and the specific measures of prevention, control or reduction of water pollution and other adverse impacts on aquatic ecosystems. Therefore, regulators and other interested stakeholders must be clear about decision-making objectives in pollution management, incorporating water pollution management in the broader river basin-based IWRM planning process to ensure water quality matches that necessary for all intended uses.

Water quality **guidelines** are scientifically derived and define the maximum allowable concentration of various substances for water uses that include drinking, domestic and livestock watering, irrigation, fishery maintenance, recreation and others. Such guidelines may be set at the national, state or basin levels. The World Health Organization's Guidelines for Drinking-water Quality[44] embody the international norms on water quality in the context of human health. The European Union Water Framework Directive[45] outlines member states' qualitative and quantitative objectives for all water bodies. Many countries use these global and regional guidelines as basis for setting objectives and establishing regulatory structures and processes.

Water quality objectives are locally specific and detail the physical, chemical, or biological characteristics of water, biota or sediment and their effects on water uses, including aquatic life support.

Water quality **objectives** are locally specific and detail the physical, chemical, or biological characteristics of water, biota or sediment and their effects on water uses, including aquatic life support. Broadly based on water quality guidelines, objectives are affected by existing local water quality, uses, movement, amount of waste discharges and socio-economic setting. The latter encompasses the national development agenda, from national priorities to forecasts for land-use changes, social and industrial progress, and agricultural development. A cost-benefit analysis of maintaining water quality sufficient for designated uses is an integral part of objective-setting, requiring consultation with and agreement of all involved stakeholders and jurisdictions.

Water quality objectives can be set for individual water bodies (including transboundary waters) or in general, for all waters within a country or region. Establishment of water quality objectives on the basis of water body classification that identifies pollution-sensitive regions is also helpful (e.g. based on drinking-water supply or aquatic life, which are the most sensitive criteria yielding the best possible level of water quality).[46]

6.3 EFFLUENT QUALITY STANDARDS

Effluent quality standards define the allowable concentration of polluting substances in discharges and are used because the cleaner the run-off, the cleaner the water system at large. In practice, developing country realities require a progressive approach of managing point source pollution to control effluent discharges while aiming to achieve acceptable surface and groundwater quality in the medium term.

44 See http://www.who.int/water_sanitation_health/dwq/guidelines/en.

45 See http://ec.europa.eu/environment/water/water-framework/index_en.html.

46 For examples from various countries' water quality classification schemes, see UNEP 1997.

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Pollution management systems often use effluent quality standards as the basis for licensing effluent discharges and enforcing environmental laws and regulations, with any noncompliance resulting in predetermined management responses (e.g. license revocation, monetary penalty). However, bringing major polluters into a management system of incentives and sanctions that reduce pollution incidence and severity, the first step of addressing water quality, has yet to be taken in many parts of the world.

Stakeholder agreement and understanding of effluent quality standards is critical, because establishing specific amounts of allowable pollutant discharges often generates controversy due to conflicting stakeholder views. The process of setting effluent quality standards can be described as balancing conservation and development: the effort to maintain a clean and safe water supply can restrict economic progress, while economic gains often result in environmental losses—specifically, the degradation of water quality as a result of agricultural or industrial pollution.

Specific to both discharge and the receiving water body, effluent quality standards are typically established either as a function of the desired water quality (i.e. in line with water quality objectives) or the limitations of treatment technologies.

6.3.1 Setting effluent standards based on water quality objectives

Defining effluent standards based on water quality objectives targets the protection of the most sensitive water uses among a number of all existing or planned uses within a basin. Assimilative capacity of the water body—the capacity to absorb constituents without deleterious effects—plays a major role, and the dilution ratio is an important parameter that reflects the relationship between the total volume of water and the volume of incoming waste. The dilution ratio affects the waste assimilation capacity of the water body. A major advantage of the water quality-based approach to setting effluent standards is the focus on solving problems caused by the conflicts among the various demands placed on water resources, particularly in relation to their ability to assimilate pollution.

For example, if the water quality objective for biochemical oxygen demand (BOD) is 3, the dilution ratio is 1:10, and the upstream BOD is 0, the effluent quality standard for BOD is 30, as follows:

$$C_2 = \frac{(F_1 + F_2) \cdot C_3 - F_1 \cdot C_1}{F_2}$$

Where:

- F_1 – upstream flow
- F_2 – discharge flow
- C_1 – concentration in upstream waters
- C_2 – concentration in discharge (effluent standard)
- C_3 – concentration in downstream waters (water quality standard)

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Using water quality objectives for setting effluent standards is sensitive not only to the effects of individual discharges, but also to the cumulative effects of the entire range of discharges into a given water body. The approach enables setting an overall limit on levels of contaminants within a water body according to required water uses, supports and protects designated freshwater uses, and maintains ecosystem functions and aquatic life. In contrast, a big disadvantage of this approach is its limited use resulting from the large seasonal waterflow variations in many parts of the world.

The cost implications of the best-tech approach are a challenge for developing countries and particularly for small industries, which often seek a compromise between stimulating industrial development and consequences of pollution.

6.3.2 Technology-based effluent standard-setting

In the industrialized world, polluters are likely to be required to meet effluent standards by using the best available technology. These standards are based on the capacity of the treatment unit and technology type. However, the cost implications of the best-tech approach are a challenge for developing countries and particularly for small industries, which often seek a compromise between stimulating industrial development and consequences of pollution. Most developing countries promote clean production, encouraging all industries to adopt methods that minimize water uses, encourage recycling, and limit solid and liquid waste.

DISCUSSION QUESTION

What are different countries' experiences on the effectiveness of effluent standards?

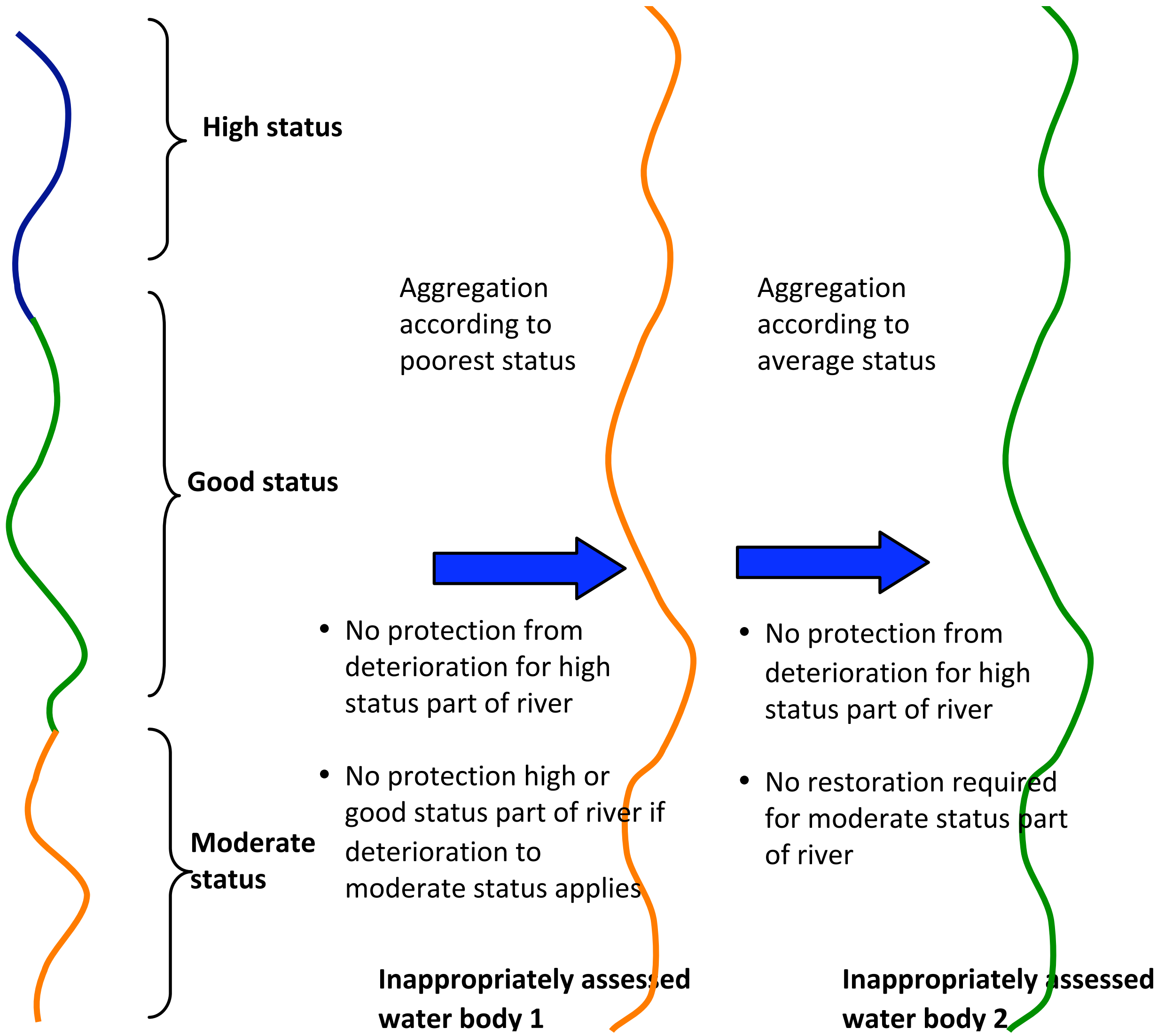
6.4 WATER BODY ASSESSMENT

Assessing the status of water bodies and associated ecosystems provides a baseline and direction for setting water quality objectives related to vulnerability and protection, including effluent standards, and for prioritizing implementation actions. Initial assessments should be sufficiently detailed to identify the most appropriate, best targeted actions for protection or recovery. Notably, an inaccurate status assessment can greatly hinder pollution management (see Figure 6.2).

Generally, a water body can be defined as a discrete and significant element of surface water, such as a lake, reservoir, stream, river or canal, part of a stream, transitional water or stretch of coastal water. Further subdivision may be made according to social and environmental geography.

An inaccurate status assessment can greatly hinder pollution management.

FIGURE 6.2 POTENTIAL IMPLICATIONS OF AN INAPPROPRIATE WATER BODY CLASSIFICATION



Source: European Commission 2003.

6.4.1 Surface water assessment criteria

Water bodies are characterized by geographical and hydrological parameters. There are four primary criteria used for assessing a water body's need for pollution protection, including:

- Boundary definition;
- Physiological characteristics;
- Status of surface water; and
- Protected areas.

BOUNDARY DEFINITION

For status assessment purposes, boundaries may be redefined for water bodies that are managed under different systems or conditions. While the most obvious and the IWRM-recommended assessment boundary—and overall water resources management level—is the river basin, certain tributaries have distinct pre-existing water quality objectives that may warrant separating them from other water resources within the same basin. Similarly, lake systems that unite water bodies with different management objectives may warrant treating parts of a larger water system as standalone entities.

UN PHOTO/MARCO DORMINO

PHYSIOLOGICAL CHARACTERISTICS

Geographical or hydromorphological features can be used to differentiate among the discrete elements of surface water. For example, the confluence of one part of a river with another could clearly demarcate a geographically and hydromorphologically distinct boundary to a water body. Similarly, lakes that feature distinct parts of varying depth and width can be divided into more than one surface water body.

Modified and artificial water bodies are delineated by the extent of changes to the underlying natural hydromorphological characteristics. Because human activity can hinder the achievement of a good ecological status, heavily modified water bodies have very specific, and often relatively high, pollution protection requirements—for example, in cases of rivers modified for land or urban drainage.

STATUS OF SURFACE WATER

A water body must be capable of being assigned to a single ecological status described by sufficient information on the pressures, impacts and uses revealed by a DPSIR analysis (see Module 5). A change in such status delineates water bodies.

Aquatic environments associated with vulnerable ecosystems should be treated as distinct water bodies. Information on the composition and abundance of aquatic organisms present in an ecosystem will indicate its status. For example, natural wetlands and mangrove ecosystems are highly sensitive and need to be identified and addressed as separate water bodies.

PROTECTED OR DECLARED AREAS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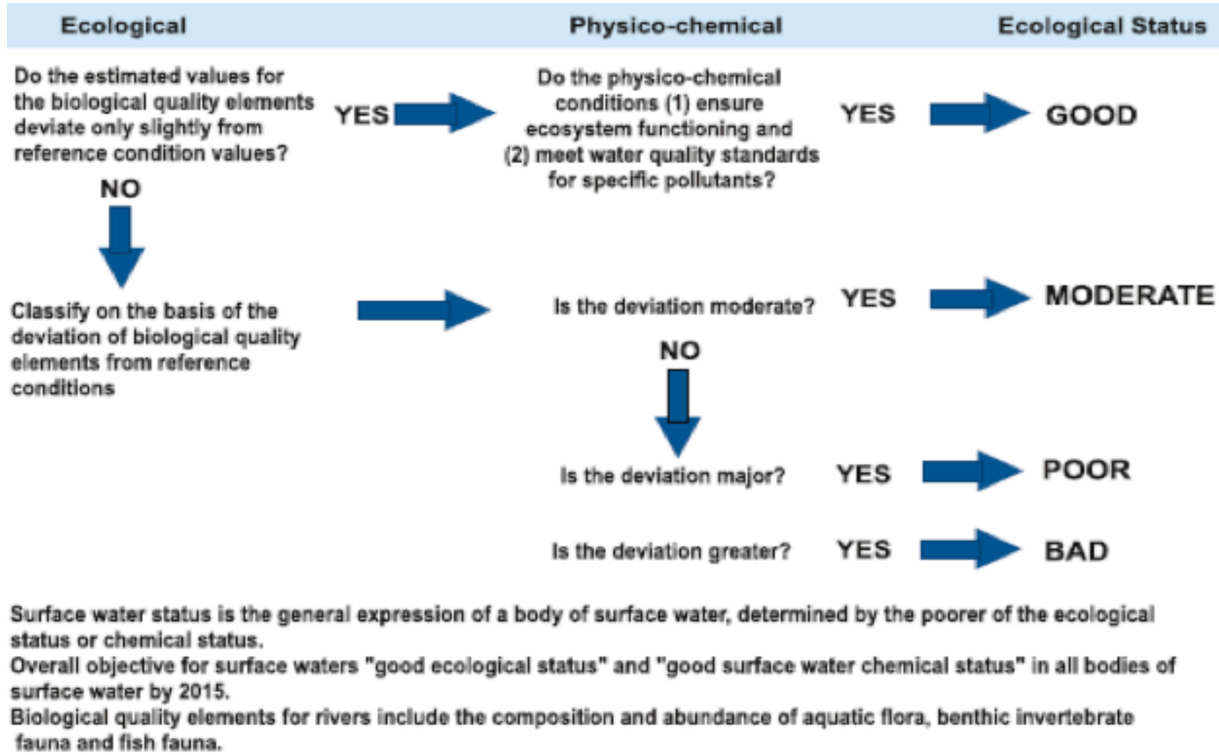
Areas designated as protected or declared for another purpose can serve to identify water bodies. In cases where a water body is neither fully inside nor outside a protected area, the body may be sub-divided into parts to ensure that its boundaries mirror those of the protected area.

6.4.2 Groundwater assessment criteria

Groundwater bodies are identified using geological boundaries in a complex and costly process. Groundwater should be delineated in all three dimensions (length, width and depth). In addition to geological boundaries, groundwater highs, flow lines and aquifer status are also used to

Aquatic environments associated with vulnerable ecosystems should be treated as distinct water bodies.

FIGURE 6.3 SURFACE WATER BODY STATUS ASSESSMENT



Source: UNEP 2010.

delineate groundwater bodies. Groundwater resources identified as threatened or important for present or future uses should receive special attention in a pollution management system,[47] The complexity of groundwater flows makes delineating and assessing the status of individual water bodies rather difficult. Long-term consequences of groundwater pollution require a very conservative approach, therefore risk identification and prevention measures are important.

47 Cap-Net 2010.

6.5 POINT SOURCE POLLUTION MANAGEMENT

Pollution prevention via process controls is the most sustainable and effective option in the long term.

Broadly, water pollution arises from point and non-point sources that vary in origin and the modes of transportation and final disposal. Point source discharges—such as those from sewerage or industrial wastewater treatment plants—are easily identified and can, in theory, be readily monitored and addressed with end-of-pipe or process controls.

End-of-pipe controls are more common, usually implemented through a regulatory system that requires polluters to meet the effluent quality standards prescribed by applicable guidelines, licenses or permits. Process controls endeavour to prevent pollution by reducing or eliminating contaminants at the source. While often regarded as a less costly and more effective way of pollution control than end-of-pipe treatment, ineffective regulations—such as those that impose no or token penalties—can make it less expensive and more convenient for polluters to dispose of the waste than to prevent generating it.

Still, pollution prevention via process controls is the more sustainable and effective option in the long term. Prevention strategies—such as the concepts of cleaner production, zero waste, energy recovery, closed cycle and others—reduce or eliminate the use of hazardous substances, pollutants and contaminants; modify equipment and technologies to generate less waste; and reduce fugitive releases and water consumption. All pollution prevention approaches adopt and build on the three Rs (reduce, reuse and recycle).

Achieving cleaner production involves understanding pollution sources (the where), causes (the why) and options for eliminating both (the how). For productive sectors that produce high numbers of polluting entities ranging from manufacturers to agro-businesses, the benefits of cleaner production include:

- Reducing production costs;
- Reducing waste treatment costs;
- Improving product and service quality;

- Achieving optimal raw material consumption and improved production efficiency;
- Improving corporate image by demonstrating social responsibility; and
- Improving long-term sustainability by reducing the environmental impact of development.

There are six prerequisites to successful practical application of cleaner production, including:

1. **Commitment:** The industry must have a policy commitment to minimizing waste, including senior management support and clear objectives, targets and time frames.
2. **Organization for action:** Multidisciplinary teams should be set up to cover all major aspects of pollution prevention processes.
3. **Audit and review:** Ongoing examination and quantification of waste streams, material consumption and other relevant processes is essential.
4. **Options for improvement:** Planning cleaner production must be rooted in estimating the costs of and prioritizing various options.
5. **Action:** Policy must be supported by coherent, concrete and time-bound implementation.
6. **Review and identification of further opportunities.**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DISCUSSION QUESTIONS

Are there any examples of cleaner production being practiced in your home area? What are the incentives that made it happen?

6.6 NON-POINT SOURCE POLLUTION MANAGEMENT

Control of non-point source pollution relies heavily on land use planning, coordination with key sectors (e.g. agriculture, industry, urban authorities) and cooperation in policy development.

Non-point source pollution occurs when water washes over land, farmland, roadways, urban and suburban residential areas. This runoff water collects silt, clay, chemicals, nutrients and toxic materials that drain into neighbouring water bodies and affect local and downstream communities and ecosystems. It also poses considerable difficulties in identifying, monitoring and controlling pollution sources and effects. A basin-level approach is essential to identify diffused pollution and assess its relationship with land use activities and pollution control policies and measures.

A pollution inventory is the first step of non-point source pollution management. The inventory should encompass elements such as:

- **Agricultural pollution sources**
  - Nutrients (nitrogen, phosphorous, other miner nutrients)
  - Pesticides (herbicides, insecticides, fungicides)
  - Soil amendments (lime, gypsum)
  - Farming patterns and agricultural practices
- **Urban pollution sources**
  - Runoff from roadways (oil, grease, silt, heavy metals)
  - Drainage from urban settlements (organic matter, microbial contaminants)
  - Drainage from human settlements with poor sanitation and waste management (environmental sanitation)


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Control of non-point source pollution relies heavily on land use planning, coordination with key sectors (e.g. agriculture, industry, urban authorities) and cooperation in policy development. Farmers will need guidance on good agronomic practices, such as proper timing for land preparation and the type, amount and time of application of fertilizers, manure or pesticides. Partial or total bans on using or importing toxic chemicals, particularly persistent organic pollutants, can be considered among other regulatory measures. Designating buffer zones (river reservation, riparian vegetation, wetlands) that separate non-point pollution sources from water bodies can also help reduce the transfer of contaminants to water bodies.

UN PHOTO/MARTINE PERRET

KEY MESSAGES

- **The central task of water pollution management is achieving water quality objectives.**
- **Progress towards objectives begins with assessing the present status of a water body in terms of hazards, their likelihood of occurrence and the severity of their impacts.**
- **Understanding risks makes it easier to theorize an expected quality status and, in turn, define water quality guidelines and objectives.**
- **Effluent quality standards are essential in controlling pollutant discharges. Since the standards are enforceable by laws and regulations, ongoing monitoring is necessary.**
- **Classifying water bodies allows prioritizing the most sensitive and vulnerable waters and ecosystems.**
- **Point and non-point pollution management should have distinct approaches based on their nature.**

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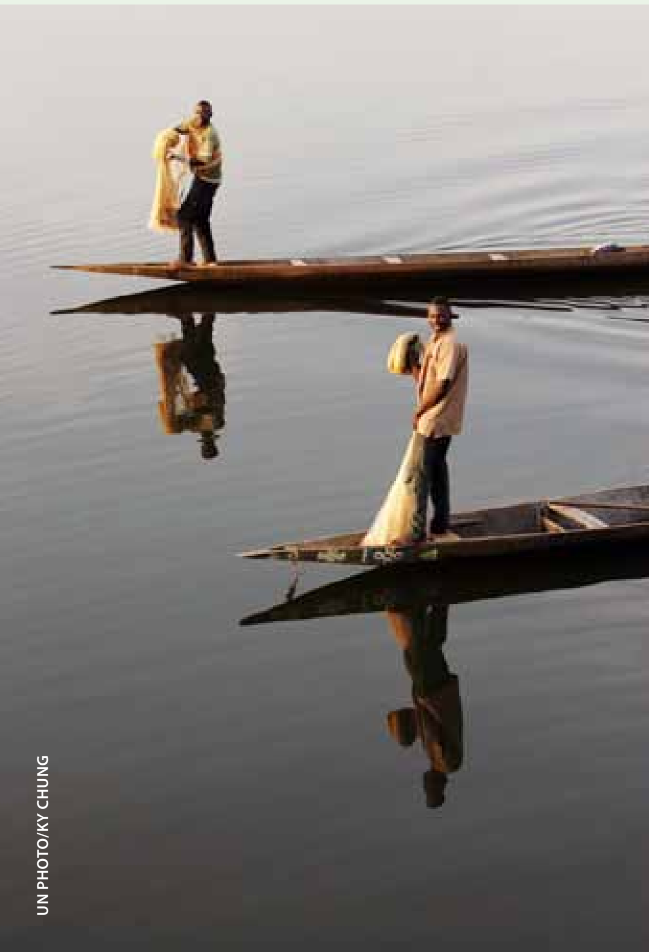
LEARNING OBJECTIVES

In this module, participants will learn about:

- **Economic and financial instruments as part of IWRM;**
- **The composition of a national water sector and the specific financial needs of the pollution management sub-sector; and**
- **The pros and cons of different financing options and the circumstances in which each is applicable.**


UN PHOTO/KY CHUNG

MODULE 7

Financing pollution management

This module begins by examining the commonalities of varied economic and financial instruments and their purposes, which include financing various water sector costs. Key costs are detailed alongside a breakdown of the different parts of a national water sector. The module outlines different financing options, explains their pros and cons, and concludes with guidance on developing a financing strategy and the composition of a financing package.

7.1 WATER SECTOR FUNCTIONS, SERVICES, COSTS AND FUNDING POTENTIAL

7.1.1 Functions and services

A nation's water sector has a range of functions and services (see Box 7.1 for a generalized overview). The starting point for developing a financing strategy is to consider—for each major function, service or group thereof—future budget estimates, potential sources and modalities of finance, and the financial status of all involved stakeholders.The financing potential of different water sector functions and services is uneven. Certain subsectors provide clearly recognizable and marketable public services and, as such, are easy to fund. These subsectors often have their own public, parastatal or private agencies. For subsectors such as hydropower (electric companies), navigation (shipping and ferry lines), urban water supply (water utilities) and forestry (timber producers), funding is normally not a problem.

In contrast, subsectors such as irrigation and wastewater services tend to be more difficult to fund, mainly because of the challenges of cost recovery from users and lacking political will to institute charges. Moreover, certain vital functions and services tend to be neglected or grossly underfunded, including integrative functions such as IWRM, environmental protection, pollution management, catchment management, flood protection, research, hydrological monitoring and forecasting, and water-related coordination, awareness-raising, stakeholder consultation and institutional capacity building.

BOX 7.1 GENERAL OVERVIEW OF NATIONAL WATER SECTOR FUNCTIONS AND SERVICES

- **Policy and coordination:** IWRM policymaking and planning, public information and stakeholder consultation, research, data collection and monitoring, legislation, emergency response, abstraction and discharge strategies
- **Regulation and monitoring:** Setting and enforcing environmental and economic performance standards for water users and service providers
- **Management and development:** Development, management (planning and operations) and protection of sources and catchments, flood protection, navigation, hydropower, environmental conservation (including wetlands), fisheries, maintaining water quality and pollution prevention
- **Bulk water supply:** Development and management of major infrastructure for agriculture, industry, power, municipal and other uses
- **Distribution of water:** Storage, treatment, transport to users, building and maintenance of water distribution networks
- **Household sanitation:** Disposal of excreta and household wastewater via dedicated facilities
- **Wastewater collection, transport and treatment:** Development and management of systems to collect wastewater from households, industries and other generators; wastewater transport for safe disposal and treatment; and disposal of sludge and re-use of treated effluent

7.1.2 Cost categories and common funding sources

Water management, development and service delivery incur recurrent and capital costs.

Recurrent costs are the continual expenses involved in operating all parts of the water sector, including wages and salaries, fuel, electricity, chemicals, spare parts and other items necessary to maintain and repair systems. Some recurrent costs are *fixed* items that do not vary with level of service (e.g. administration salaries, office rent, research, monitoring, meter reading and routine maintenance). Other items are *variable* and can increase or decrease based on the level of service provided (e.g. pumping costs and wastewater treatment costs as part of pollution management).

Capital costs are those associated with large investment items, including:

- Infrastructure (e.g. dams, urban distribution networks, sewerage systems, wastewater treatment plants);
- Resource development (e.g. catchment protection, groundwater well drilling);
- Major repairs;
- Modernization and expansion (e.g. water treatment plant upgrade); and
- Rehabilitation of old or broken infrastructure.

For recurrent cost funding, the most sustainable source is user charges, including cross-subsidies among different user categories to improve social equity.

All such items normally need specific financing provisions. In a mature wastewater system, the capital cost of wastewater services is largely met by user charges. In developing countries, government grants, soft loans and Official Development Assistance (ODA) are commonly used to cover capital costs.

For recurrent cost funding, the most sustainable source is user charges, including cross-subsidies among different user categories to improve social equity. Where governments are willing and able to subsidize water and wastewater services, funding can also be allocated annually from central or local government budgets replenished through taxation.

7.2 ECONOMIC AND FINANCIAL INSTRUMENTS

Although some instruments can perform both economic and financial functions, economic and financial instruments generally differ in purpose. **Economic** instruments influence user behaviour towards water, allocation of water resources and water pollution. According to IWRM goals, economic instruments prioritize the Three Es: social Equity, Environmental sustainability and economic Efficiency (see Module 2). **Financial** instruments generate revenue for water sector operation and development, and are designed to support socio-economic policies and strategies.

The two types of instruments go hand in hand, and the same instrument may both influence user behaviour and raise funding for operation and maintenance. For instance, imposing financial penalties for failing to meet effluent standards can encourage polluters to monitor discharge composition more closely while also generating revenue. (See Box 7.2.)

BOX 7.2 ECONOMIC AND FINANCIAL INSTRUMENT EXAMPLES AND IMPACTS

- **Water tariffs raise operating revenue for water systems (financial impact) but can be adjusted to also influence consumer behaviour towards water by encouraging more careful use and promoting conservation (economic impact). An *optimal tariff* in classical economic terms raises the necessary revenue (financial impact) with minimal impact on consumption, or least 'distortion' (economic impact).**
- **Pollution taxes, if these succeed in the aim of eliminating pollution (economic impact), will eventually raise zero revenue (financial impact).**
- **Subsidies and tradeable 'permits to pollute' are transfer mechanisms that do not raise revenue but a im to implement socioeconomic and environmental policies (economic impact).**

DISCUSSION QUESTION

Can you provide an example of economic and financial instrument that could be used in pollution management?

Consequently, neither economic nor financial instruments can be developed or used in isolation; rather, both must be integrated into broader-scope water sector management and national policies that generate the 'three Ts'—taxes, tariffs and transfers, the three sources of funds. The water sector covers all aspects of the development, management and use of water and supporting physical infrastructure; all related functions and services need adequate funding, including the functions and services that target water pollution management: planning, data gathering, policymaking, institutional support and reform, regulation, legislation, compliance and awareness-raising (see Box 7.3).

Commonly employed water sector economic instruments include tariffs, subsidies, cross-subsidies and other incentive-based measures, such as water trading and effluent charges. Although typically used to promote efficient allocation and use of water resources, economic instruments may also target the broader objective of equitable and sustainable water resources allocation and use. In line with the central IWRM focus on integration, economic instruments work best when they are complementary to—and complemented by—relevant policy, regulatory, institutional, technical and social instruments.

BOX 7.3 ECONOMIC AND FINANCIAL INSTRUMENTS IN IWRM CONTEXT

Economic and financial instruments are becoming increasingly important in making IWRM decisions that both improve water resources management and contribute to the broader social agenda.

As water becomes scarcer, its value rises and exacerbates existing inequalities. Economic instruments work to raise producer and consumer awareness of such issues. Charging for detrimental behaviour stresses the need to ensure efficiency, improve equity of access and protect the environmental sustainability of water resources—delivering on the Three Es that embody IWRM goals.

Financial instruments pursue funding for water-related projects and decisions, helping sustain the water sector and ensure a continuous flow of user benefits. Certain financial instruments can also contribute to achieving social IWRM goals, for instance, by ensuring that water costs are affordable for the poor or varying pricing for different uses based on their environmental impacts.

Economic instruments are charges levied to encourage decision makers to alter their views and actions in a specific direction. Because economic instruments are not designed to recover costs, the income generated has flexibility of its use - for example, be used to invest in water and sanitation services targeting the poor or addressing inequities in the water sector or use for wastewater treatment.

In contrast, financial instruments are designed specifically to raise money to finance water sector activities. The focus of such instruments is on the resulting revenue and how it relates to the financial costs of the activities that must be funded.

The distinction between economic and financial instruments is not entirely neat or rigid. As definitions imply, both economic and financial objectives can be met by a single instrument. Water tariffs are a clear case in point: Tariffs are a financial instrument with considerable and varied economic impact potential. From a financial perspective, commercially oriented water utilities set tariffs to meet the objective of covering their operational, maintenance and capital costs. Performance is measured by financial indicators such as net profit, return on capital and credit worthiness (ability to repay loans). From the economic viewpoint, water utilities assess tariffs for their potential to contribute to achieving multiple water sector objectives, from ensuring adequate service delivery to existing water consumers to delivering equity improvements that increase peoples' access to water and ensuring environmental sustainability. A water utility may, therefore, set a tariff below cost for the first few cubic metres of water—and above cost for subsequent cubic metres, which encourages basic household uses by the poor while discouraging excessive uses and waste.

The best way of ensuring that the financial objectives of a water utility support national economic interests is to collaborate with an independent regulator vested with adequate authority.

7.3 FINANCING POLLUTION MANAGEMENT

7.3.1 Financing pollution management as part of IWRM financing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Water institutions are highly country-specific, hence the financing structure must be equally tailor-made. However, a few common principles can guide putting together a financing strategy.

- **Use public finance for public good**. Certain activities possess clear public good features and have strong external benefits (e.g. environmental protection, wetland biodiversity protection, pollution management, flood control, forestation, catchment protection and policymaking). There is a strong case for continuing to use public funding for these important non-commercial activities that cannot be funded from private sources.
- **Recover costs of services used for productive purposes**. Introduce charges for the use of water or wastewater services, thus commercializing the services. Water and sewerage agencies may be able to bundle profitable and unprofitable services together to cross-subsidise the latter. For household water and sanitation, tariff design should account for user willingness and ability to pay.
- **Delegate financial power to lowest appropriate level** (e.g. in setting tariffs, levying pollution charges, extending loans), in line with the widespread delegation of service responsibilities to decentralized agencies. To ensure the effectiveness of decentralizing responsibilities, financial power and responsibility should be delegated alongside services. This shift requires a major local capacity-building effort in many countries, with appropriate support and controls from central government.
- **Increase self-financing of service providers**. Potentially self-financing projects and institutions should be encouraged to improve their finances and attract a wider range of funding sources. Peer group comparisons or benchmarking of performance should be used.

UN PHOTO/MILTON GRANT

- **Maximize external grants**. It is sensible to maximize take-up of available grants before seeking other funding sources. However, ODA should also be used to leverage other sources of funds and to create incentives (e.g. through output-based aid), while avoiding aid dependency and reducing the pressure for essential long-term reforms.
- **Share costs of multi-purpose schemes with sectors** where water resources create other products and services (e.g. hydropower production dam, flood protection, irrigation and recreation).
- **Capture externalities of water in monetary form and apply the proceeds to IWRM**. Applying to the polluter-pays principle, the release of untreated effluent into the water supply should be taxed. The proceeds may be directed back into the water sector, e.g. through an environmental fund or specific grants and loans for wastewater treatment or remediation of specific streams.
- **Tap into commercial sources of funds** when water and sewerage agencies or service providers achieve sufficient autonomy, capacity and creditworthiness. Each of such sources—e.g. commercial banks, International Financial Institutions, bond issuers, private equity or microfinance agencies—presents distinct pros and cons; however, central governments and external guarantee and insurance techniques can improve terms of access.

DISCUSSION QUESTIONS

Should people be compensated for damage caused by pollution, such as destroyed crops, lost wildlife, and illness or death? Who should pay?

7.3.2 Available financial instruments

Ultimately, water sector services are paid for by the three Ts: users pay **tariffs** and **taxes**, while national governments and external aid agencies provide subsidy **transfers**. All loans and private equity investments have to be serviced from future revenues and, as such, do not cover costs but merely offer a way to defer their impact on society.

The different financial instruments available fall into five broad categories (see Box 7.4):

- Usage and service charges;
- Government support;
- External grants and loans (ODA);
- Philanthropy; and
- Commercial loans, equity and private sector participation (PSP) schemes.

BOX 7.4 WATER SECTOR FINANCING INSTRUMENT EXAMPLES

Usage and service charges

- Water abstraction charges
- Water tariffs for households, industries, farmers and other major users
- Sewerage and effluent charges
- Water pollution charges and taxes
- Licence fees and charges for specific services
- Flood protection levies

Government support

- Grants
- Guarantees
- Support from national, state or municipal budgets

External grants and loans

- ODA
- Financial intermediaries and development banks
- Concessional/soft loans

Philanthropy

- Philanthropic agencies and funds
- NGO and civil society partnerships

Commercial loans, equity and private sector participation

- IFI loans
- Commercial bank loans and microfinance
- Bonds
- Private equity
- External guarantees and risk sharing
- Build–operate–transfer (BOT) or build–own–operate–transfer (BOOT) schemes
- Concessions

BOX 7.5 GUIDING PRINCIPLES FOR TARIFF IMPLEMENTATION

- Tariffs must maximize efficient allocation of water resources.
- Water users should perceive the tariff as fair.
- Rates must be equitable across customer classes.
- Tariffs must bring sufficient revenue.
- Tariffs must provide net revenue stability.
- The public must understand the rate-setting process.
- Tariffs must promote resource conservation.
- Tariff-setting process should avoid rate shocks.
- Tariffs must be easy to implement.
- Water must be affordable.
- Rates must be forward-looking.
- The rate structure must attempt to reduce administrative costs.
- Tariffs must account for environmental costs.
- Water prices must account for supply characteristics such as water quality and supply reliability.
- Tariff structure must vary depending on consumption measurement.
- Tariff rate structures should endeavour to evolve more sophisticated mechanisms that account, for example, for daily peaks and seasonal variations in water demand.

USAGE AND SERVICE CHARGES

Authorities levy various tariffs and charges on water users and those discharging wastewater, the polluters. Theoretically, these economic instruments aim to influence user behaviour (i.e. to encourage more careful use of water or lower pollutant discharges), hence there is no particular mandate or reason to return all the revenues generated to water service providers. In practice, however, it is typical for such revenues to be used to cover some or all of the costs of water and wastewater services; for example, revenues are often earmarked for water, sanitation and hygiene (WASH) programmes.

It is important to consider both options: allowing service providers to retain revenues to cover expenses or disbursing revenues through the central treasury as part of national budgetary processes. In societies with highly decentralized water services and adequate local autonomy and capacity, it is typically more efficient for service providers to control the use of their own revenues. This arrangement also removes an element of uncertainty, whereas national budgetary processes can be arbitrary and cumbersome.

Charges and tariffs need to fulfil certain criteria in order to overcome resistance from water users facing new costs (see Box 7.5). Payees must see any charge or tariff system as fair and necessary.

WATER ABSTRACTION CHARGES

Water abstraction charges are levies on water companies, industries, farmers and other actors who directly abstract water from surface or groundwater sources. Apart from recovering some of the public costs of water resources management, these charges are intended to encourage water conservation, and to reflect the wider costs of water abstraction to society and the environment. Charges for the abstraction of surface and groundwater should bear some relation to each other; otherwise, the lower priced water source could be overused.

DISCUSSION QUESTIONS

Should anyone be exempt from water abstraction charges? Why?

WATER SUPPLY TARIFFS

The costs of abstracting, storing, transporting, treating and distributing water to households, agricultural producers and the industry are recovered partially or wholly by user tariffs. Flat rate tariffs will suffice to raise revenue, but volumetric tariffs are necessary to influence water use. Volumetric tariffs require metering or other methods of measuring usage, which is not feasible in every context (e.g. rural connections or poor urban communities).

Costs of wastewater services such as sewerage, wastewater treatment and removal of sludge are often recovered through a surcharge on the drinking water tariff, for two reasons: the high correlation between overall water use and wastewater volume, and consumer resistance to paying for wastewater services separately.

There are various ways to make tariffs affordable to poor consumers, for example:

- Using cross-subsidies from other consumer segments;
- Ensuring basic quantities of water are made available to everyone, free or at a low unit rate;
- Employing progressive tariffs, where charges per unit increase with the volume consumed); and
- Covering poor households' water bills from social security payments to avoid consumption distortion (though this is not feasible in all countries).

Flat rate tariffs will suffice to raise revenue, but volumetric tariffs are necessary to influence water use.

When setting tariffs in developing countries, practitioners commonly use an affordability benchmark of 3–5 percent of average household income to cover water services.[48] The nature of averages means that the wealthiest population segments spend a much smaller share of their income on water, while the poorest are furthest from the statistical income average and are considerably more burdened by water service costs. These inherent inequalities are exacerbated contextually: The wealthy tend to have social, business and political connections that may influence the price of water services, while the poor are often forced to supplement their consumption from informal providers whose pricing is unregulated and subject to water supply fluctuation.

48 Including both freshwater and wastewater services. In countries with rudimentary sewerage, the tariff overwhelmingly reflects the cost of supply. As more sophisticated sewerage is provided, the wastewater component of the tariff rises.

BOX 7.6 EXAMPLE OF FINANCING FROM ABSTRACTION AND DISCHARGE LEVIES: FRENCH WATER AGENCIES APPLY POLLUTER/USER-PAYS AND WATER-PAYS-FOR-WATER PRINCIPLES

The 1964 French Water Law (modified in 1992 and 2006) set up a water agency in each of the country's six main river basins. The agencies are administrative public institutions with civil status and financial autonomy.

Agencies are financed using the polluter/user-pays principle. Each agency levies water charges on withdrawals and discharges that affect water quality and modify the water regime. For industries, the charges are calculated according to industry type and amount of pollution produced. For domestic users, the charges are calculated for each community according to both permanent and seasonal populations, and are collected from users together with payments for metered water consumption.

The rates are determined by each agency and adapted to the priorities and quality objectives defined for each basin. Rates must be approved by each basin's governing body, a multi-stakeholder committee composed of representatives from central and local government and water users (industrialists, large regional developers, farmers, water supply and sanitation companies, fishermen, and associations for the protection and conservation of the environment).

Based on the water-pays-for-water principle, 90 percent of the funds collected are then reallocated as loans and subsidies to local communities, industries, farmers and other groups. The objectives are to:

- Abate pollution (e.g. construct, extend or improve purification plants and wastewater collection systems; introduce cleaner production processes);
- Develop and manage surface and groundwater; and
- Restore and maintain aquatic environments.

The remaining 10 percent of revenue cover water agencies and river basic committees' operating costs. For the current six-year action plan period, the funds to be collected are estimated at Euro 11.6 billion, which will support basin investments or water resource activities to the value of Euro 10.2 billion.

Note: For additional information, see http://www.lesagencedeleau.fr.

At the same time, there is growing evidence of consumer willingness to pay for access to water or improved levels of service. Affordability is not an issue for industrial and commercial consumers; in many countries, revenues from these sectors are used to cross-subsidise domestic water use. Farmers who receive water from public irrigation networks are also commonly subsidized.

SEWERAGE AND EFFLUENT CHARGES

Households, industries and other commercial users that discharge wastewater into a public sewer normally pay a surcharge on water bills to cover wastewater disposal costs. Major sources of effluent, such as industries, may be subject to a special trade effluent charge based on the strength of effluent going into public sewers and the presence of specific pollutants.

WATER POLLUTION CHARGES AND TAXES

Pollution charges and taxes are environmental levies on wastewater effluent discharged directly into natural watercourses. Tax structure and rate typically depend on the concentration of specific pollutants, aiming to encourage in-plant effluent treatment prior to discharge. Ideally, the tax structure should also reward the release of adequate amounts of clean effluent, which are necessary to maintain river flows and dilute polluted wastewater.

LICENCE FEES AND CHARGES FOR SPECIFIC SERVICES

Some of the costs of maintaining the water volume and quality of aquatic bodies can be recovered directly from people and companies that depend on such services. Examples include fishing licence fees, transport lock charges, hunting entry fees, and the supply of maps and hydrological data for those who need and depend upon the water resource for their businesses.

GOVERNMENT SUPPORT

UN PHOTO/LOGAN ABASSI

Central governments provide financing—in the form of grants, soft loans, bonds or guarantees to subnational agencies—for capital spending on water by channelling funds to local authorities or public water companies (see Box 7.7). Where foreign aid is available, it typically flows through central government systems before passing to local authorities. Tariff revenue from water provision may either be retained by the local water utility or returned to general public coffers.

Advantages of central government funding for capital projects include:

- Fundraising is related to national financial capacity and can help avoid local over-borrowing and debt problems;
- The national treasury can get better financial market terms than local authorities;
- Central authorities can set national priorities and steer funds towards urgent cases, ensuring equity between richer and poorer parts of a country; and
- The foreign exchange risk of loans is borne by central government.

BOX 7.7 NATIONAL FUNDING FOR RECURRING WATER SECTOR COSTS

There is a number of ways for the central government's annual budget to support recurring water sector costs. However, when structuring such arrangements, it is important to balance advantages and disadvantages. The central budget can, for example:

- **Cover fixed costs** (e.g. salaries, vehicles and offices for water sector staff). Establishing a distinct central water agency is typically accompanied by a budget allocation from the national treasury, hence the central government often covers all or some of the water sector's fixed costs. Similarly, in countries where water services are the domain of national environmental or health agencies, fixed costs associated with water resources management are part of each such agency's budget. For countries with no such agencies or arrangements currently in place, future plans for central government funding for recurring water sector costs should prioritize long-term sustainability.
- **Cover variable costs** (e.g. power, chemicals). Variable costs are a function of use and are, as such, most efficiently addressed by charging users for water services. Central government financing can be difficult to manage given unpredictable usage requirements and can also function as an economic disincentive to consumers: can a country effectively reduce waste in the absence of volumetric usage or wastewater transport and removal charges?
- **Underwrite financial deficits incurred by local water utilities.** Central government financing can be critical as a budgetary stop-gap; for example, in cases of catastrophic point source pollution, natural disasters, or even inability to fund certain critical functions or interventions. However, national budget support cannot become the proverbial blank cheque, which would remove any incentive for water utilities to strive to improve their finances.
- **Provide subsidies for specific purposes** (e.g. free water for deserving cases, sanitation or drought preparedness programmes). If used over-broadly, government subsidies can have significant negative impacts (e.g. overconsumption, supply shortages, rising tax rates). There are also challenges of measuring success and serious operating inefficiencies that cause a staggering portion of subsidy funds to be diverted to places other than intended; estimates suggest that more than half of all government subsidy funds do not end up with their intended recipients.* Targeted or 'smart' subsidies can help avoid some of these disadvantages, particularly if they are predictable and transparent.

* See OECD 2010.

On the other hand, there are also certain disadvantages, such as:

- Decisions on water funding become more politicized at the national level;
- Central authorities may prioritize the water sector lower than local governments;
- Funding may become dependent on a fragile national fiscal situation;
- Local service providers are discouraged from developing financial self-sufficiency; and
- External donors and other financiers are unable to develop close relationships with actual providers.

BOX 7.8 OUTPUT-BASED AID – AN ALTERNATIVE TO UPFRONT GRANTS

Output-based aid (OBA) is often advocated as an appropriate solution for the water sector.

OBA is a form of results-based financing designed to enhance access to and delivery of infrastructure and social services for the poor through the use of performance-based incentives, rewards, or subsidies. OBA links the payment of aid to the delivery of specific services or 'outputs', such as connection of poor households to electricity grids or water supply systems, installation of solar heating systems, or prenatal care and safe delivery services for new mothers.

In an innovative case in Kenya, World Bank OBA underpins a programme aiming to extend water and sanitation to rural communities, financed by a local microfinance agency. Once the programme is fully implemented and generates revenue from user charges, the microfinance loan will be partially repaid by OBA.

Sources: GPOBA undated, Mehta and Virjee 2007.

EXTERNAL GRANTS: OFFICIAL DEVELOPMENT ASSISTANCE

A wide variety of international agencies offer grants and concessional loans.[49] As a core financing principle, developing countries should aim to maximize their uptake of ODA grant money before contemplating commercial financing for the water or any other sector. Even grants may have significant transaction costs and inconveniences, and pursuing funding from many different sources can tax the management abilities of national authorities.

Grants are transparent and simple. They avoid repayment obligations and debt overhang—and can be blended with other funding vehicles to produce a suitable financing package for a particular project.

At the same time, grant appraisal requirements and conditionality are usually more burdensome than those of commercial loans. Grants may also carry political and commercial obligations, explicit or implied. Each donor has a different procedure, which could be burdensome and have a lengthy disbursement period. Donors also tend to use different technical products, which complicates procurement, and may further insist on their own institutions and special project units that do not match national systems.

As such, grants can be difficult to integrate with water programmes. Reliance on ODA also reduces sustainability: the 're-entry' challenge after aid ceases can cause service and function disruption or end, if the national government is unwilling or unable to continue funding. Output-based aid is an example of ODA that offers an alternative to upfront grants (see Box 7.8).

49 A concessional loan is one that is available on better terms than those provided by private financial markets–lower interest, longer maturities and/or grace periods before interest or repayments are due. In order to qualify as ODA recognized by the OECD Development Assistance Committee (DAC), concessional loans have to contain a 'grant element' of at least 25 percent. In technical terms, the grant element is the discounted value of the loan's repayment stream, at the DAC standard discount rate, expressed as a percentage of the face value of the loan.

KEY MESSAGES

- **All recurring and capital costs of water sector functions and services need to be adequately financed, but not all have equal funding potential.**
- **In mature water sectors, authorities generate revenues by using varied economic and financial instruments to levy tariffs and charges on water users and polluters.**
- **Economic instruments influence user behaviour towards water, allocation of water resources and water pollution, prioritizing the IWRM goals of social equity, environmental sustainability and economic efficiency.**
- **Financial instruments generate revenue for water sector operation and development, and are designed to support socio-economic policies and strategies.**
- **Economic and financial instruments often overlap and work hand in hand.**
- **The key instruments for financing the water sector include: usage and service charges; government support; external grants and loans (ODA); philanthropy; and commercial loans, equity and PSP schemes.**
- **The polluter/user-pays and water-pays-for-water principles are at the core of water sector financing: Those who use and, through such use, cause harm to water resources shall compensate by paying for related management, clean-up and other required services. The funds collected from the water sector shall remain within it, not disappear into the state coffers.**

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LEARNING OBJECTIVES

In this module, participants will learn to:

- **Appreciate the benefits of stakeholder participation in pollution management;**
- **Identify the categories of stakeholders (general and context-specific);**
- **Describe stakeholders roles and responsibilities essential to effective water quality management; and**
- **Identify effective stakeholder engagement strategies.**

UN PHOTO/PAULO FILGUEIRAS

MODULE 8

Working with stakeholders

8.1 STAKEHOLDER ROLE IN POLLUTION MANAGEMENT

Water pollution affects everyone: polluters, users, regulators, environmentalists, policymakers and civil society actors with different role and interests. The central water pollution management processes of risk assessment, setting water quality objectives and effluent quality standards, licensing, monitoring use and quality, implementation of noncompliance legislation, reporting, research and education require a series of consultation among different parties. Stakeholder participation rooted in sharing of information and transparency is critical to balancing the interests of these varied groups and ensuring the overall effectiveness of the collective effort at water pollution management.

Wide-ranging and participatory stakeholder involvement has multiple benefits, including:

- **Informed decision-making:** Stakeholders possess valid information on water pollution and its health and ecosystem impacts. Quite often, local-level information and evidence are inaccessible at higher administrative levels, and stakeholder participation is often the most efficient and cost-effective way of obtaining such information.

Stakeholders in pollution management processes include any individual or group that is responsible for taking actions that lead to pollution (users and polluters), is affected by such action, or can aid or prevent implementation of water quality-targeting measures.

- **Equity and inclusivity:** Wide-ranging participation recognizes and protects the interests of those most vulnerable to the effects of water pollution: the poor, women and fragile ecosystems.
- **Consensus-building:** Stakeholder engagement and the need to compromise with others from the outset of development projects fosters consensus-building, ultimately reducing conflicts during implementation.
- **Ownership:** The ability to voice their concerns fosters stakeholder buy-in and mobilizes social capital, largely unhindered by incidence of disagreement and compromise.
- **Cost-effectiveness and efficiency:** Stakeholder participation often leads to various forms of volunteerism, such as community members sharing information or participating in advocacy and mobilization activities. Business, industrial and other established stakeholders may contribute services, provide meeting facilities or even fund specific activities. All such contributions reduce costs and improve effectiveness of implementation and monitoring.
- **Partnership-building for the long term:** Ongoing communication between polluters, victims and regulators can ultimately lead to building long-term collaborative relationships**.**

Individual and group stakeholders also obtain multiple benefits through participation, including:

- **Recognition:** Groups affected by pollution are identified and accepted.
- **Trust:** Affected parties have more trust in the water pollution management system given involvement in consultations.
- **Solutions:** Polluters find solutions for the problems raised by the affected parties.
- **Ownership:** Each stakeholder has the power for effective implementation of compliance measures.
- **Information:** Information on water pollution, solutions and actions is shared.
- **Assistance and support:** Polluters and victims receive help to solve their problems.
- **Success:** Collaboration leads to finding solutions to common problems and, ultimately, to achieving water quality objectives.

DISCUSSION QUESTION

Why would you want to participate in a stakeholder meeting on water pollution?

8.2 WATER POLLUTION STAKEHOLDER CATEGORIES

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Stakeholders in pollution management processes include any individual or group that is responsible for taking actions that lead to pollution (users and polluters), is affected by such action, or can aid or prevent implementation of water quality-targeting measures. All stakeholders can be broadly segmented into five groups:

1. **Polluters** include industrial and agricultural producers, mining operations, domestic consumers and any individual, company or institution that discharges wastewater.

2. **Victims** encompass all water users downstream of a pollution site and can include communities, business and industrial establishments, ecosystems and aquatic life. Vulnerable and marginalized groups, whose voices are rarely heard because of lacking access to decision-making, are a particularly important sub-segment to engage in stakeholder consultations.

3. **Regulators** are institutions such as government ministries and departments, specialized water agencies or others tasked with setting standards and regulations, implementing them and monitoring compliance.

4. **Financial and implementing partners**—donors and investors who fund water quality projects for profit, and the local businesses and NGOs tasked with on-the-ground implementation—are an influential stakeholder group that can positively or negatively affect water pollution management processes and outcomes.

5. **Interested observers** are virtually unlimited, vary in levels of engagement and influence, and include, for example: environmentalists, social activists and watchdog civic groups, all largely focused on conservation and human rights; community-based and non-governmental organizations of varied interests (e.g., women's group, manufacturer association); policymakers and politicians interested in publicity but responsible for policy setting; members of the media, who are opinion makers that tend to fall on the side of the public as a group; and academic experts and researchers who possess substantial knowledge of the water sector and have a scientific interest in pursuing additional knowledge.

To fully understand stakeholder needs and possible contributions, stakeholders can be categorized by impact of pollution and influence over water pollution management.

FIGURE 8.1 STAKEHOLDER ANALYSIS

A. HIGH INTEREST/IMPORTANCE, HIGH INFLUENCE These stakeholders form the basis for an effective coalition of support for the project. **Management approach:** keep satisfied	**B. HIGH INTEREST/IMPORTANCE, LOW INFLUENCE** These stakeholders require special outreach for their interests are to be protected. **Management approach:** manage closely
C. LOW INTEREST/IMPORTANCE, HIGH INFLUENCE These stakeholders can influence the outcomes of the project, but their priorities are not those of the project. They may pose a risk or an obstacle for the project. **Management approach:** monitor and respond as needed	**D. LOW INTEREST/IMPORTANCE, LOW INFLUENCE** These stakeholders are of least importance to the project. **Management approach:** keep informed


CAP-NET

To fully understand stakeholder needs and possible contributions, stakeholders can be categorized by impact of pollution and influence over water pollution management (see Figure 8.1).[50] The most affected people often have little influence on decision-making, while highly influential stakeholders may not have adequate understanding of the issues or the grievances of the affected.

An important outcome of this categorization is gaining an understanding how to ensure that voices are heard from all 4 of the boxes. Identifying the different stakeholders is a starting tool in stakeholder participation and can be quite complex (see Box 8.1).

BOX 8.1 IDENTIFYING WATER POLLUTION STAKEHOLDERS: SRI LANKA, 2007

In 2007, more than 500 children were admitted to hospitals in one day reporting water borne disease as a result of faecal contamination in drinking water in central Sri Lanka.

- **Who contaminated the water?** Upstream dwellers (by poor sanitation practices)
- **Who was affected?** Children who drank water downstream
- **Which agency was responsible for safe water supply?** National Water Supply Board
- **Who was responsible for public health?** Medical Officer of Health
- **Who was blamed?** Urban council (local administration)
- **Who was interested?** Media, politicians, community, educators, researchers
- **Who was responsible for maintaining water quality in water bodies?** Ministry of Environment
- **Who paid the costs of the victims?** Parents of the affected children, public health ministry
- **Who should improve sanitation of the upstream dwellers?** Management of tea estates and the communities
- **Who paid for improved sanitation?** Non-government organizations
- **Who educated the people upstream?** Teachers, researchers, government officials and Non-governmental organizations

50 Cap-Net 2005.

8.3 STAKEHOLDER ROLES AND RESPONSIBILITIES

Each stakeholder group is unique in terms of views, knowledge and perceptions (see Table 8.1). Notably, stakeholder interests do not necessarily remain constant and should be closely monitored throughout water pollution management processes to ensure continuous engagement and support for the work.

UN PHOTO/RICK BAJORNAS

8.3.1 Government

As trustees or guardians of natural resources, governments play a central role in pollution control or environmental protection, ensuring alignment with national policies. Line ministries all have an investment and relationships in the water quality sector and can assist in tasks such as:

- Cross-sectoral coordination (cooperation between ministries and departments);
- Policy development on pollution management;
- Linking government and civil society at river basin, regional and local levels;
- Empowering stakeholders through education, awareness-building and publicity; and
- Stakeholder management and facilitation (e.g. advocacy, conflict management).

Untreated industrial wastewater often gets discharged into water bodies due to high costs of treatment, ineffective treatment facilities or ignorance.

8.3.2 Polluters

In point-source pollution resulting from industrial activities, pollutants vary depending on production process. Typically, contaminants demand high oxygen (BOD) or are toxic to the users. Effluent should be treated, before discharge into water streams, or recycled within the industry. However, untreated wastewater often gets discharged into water bodies due to high costs of treatment, ineffective treatment facilities or ignorance. Industries require a responsive relationship with people living in the vicinity, downstream beneficiaries and regulating bodies.

TABLE 8.1 STAKEHOLDER ROLES AND RESPONSIBILITIES IN WATER POLLUTION MANAGEMENT

WATER POLLUTION MANAGEMENT FUNCTIONS	STAKEHOLDER GROUP	ROLES AND RESPONSIBILITIES
Risk assessment	Victims	Reporting, sharing information
	Experts/researchers	Collecting information and assessing risk to public health and ecosystems
	Regulators	Risk information dissemination to relevant authorities for action
Establishing water quality objectives	Users	Sharing information on water quality requirements
	Policymakers	Setting national priorities
	Experts/researchers	Classifying water bodies and defining water quality requirements
	Civil society	Sharing information on trends and ecosystem services and requirements
	Regulators	Coordinating stakeholders
Setting effluent quality standard	Polluters	Sharing information on raw materials used, contaminants released, available technology and effluent treatability level
	Experts/researchers	Providing technical inputs and advisory services
	Civil society	Educating stakeholders on effluent quality standards
	Regulators	Evaluation of polluter applications with other stakeholders, and granting permits and licenses
Granting permits or licenses	Regulator	Collecting payments, regular permit updates and renewals, ensuring public transparency of licenses
	Civil society	Opinion gathering and reporting
	Media	Publicity and opinion making
Compliance measures	Polluters	Wastewater treatment (before end of pipe), improving process efficiency, payment/compensation for lack of compliance
Monitoring and reporting	Civil society	Compliance monitoring and reporting
	Polluters	Effluent monitoring and reporting
	Regulators	Monitoring and reporting
Research, education, awareness-building	Experts/researchers	Collecting information, analysis, documentation and communication
	Regulators	Coordinating capacity-development programmes
	Media	Public awareness-building, education, information dissemination

BOX 8.1 CORPORATE SOCIAL RESPONSIBILITY

Corporate social responsibility (CSR) is a framework that integrates social and environmental concerns into business objectives. All industry and business ventures are being challenged to be more innovative and competitive, more productive and profitable, and more responsible and sustainable. A meaningful collaboration and engagement with key stakeholders is essential to improve public credibility and confidence.

Contributing to environmental protection with physical infrastructure and social capital is increasingly seen as a necessary part of doing business through social investment. CSR is increasing the expectation that companies be more open, more accountable and prepared to publicly report on their social and environmental performance.

Private-public partnerships for water pollution management can be effectively pursued under the CSR framework. CSR activities directly related to or supporting water pollution management should be encouraged and promoted.

Human settlements pollute water bodies. Organic loads and pathogenic contaminants are unique features of domestic effluent. Utilities providing water and sanitation services must work with communities on conservation, safe disposal of wastewater, and effective health and sanitation practices.

Farming is a source of non-point pollution. Excessive use of agro chemicals (fertilizer, herbicides, pesticides and amendments) leads to wash-off and leaching into surface and groundwater bodies. Many countries do not have an effluent quality standard for farm lands. Consequently, non-point source pollution is difficult to control and requires special attention, as it increases health hazards and natural habitat degradation.

8.3.3 Civil society

Civil society is a complex mix of people who represent various social, economic and topical groups. Civil society is both responsible for a certain share of water pollution and is affected by it.

However, civil society groups and individual stakeholders are largely not heard, not aware of water pollution management processes and not legally recognized. At the same time, such bodies often have information and knowledge of traditional practices on water pollution control. Prevention of pollution, monitoring of water quality, implementation of regulations, regular reporting or communication with other stakeholders are some of the key roles playoff by civil society stakeholders.

Gender-sensitive stakeholder analysis and participatory consultation methods are essential to facilitate greater expression and consideration of both women's and men's voices. Women are typically the primary stakeholders, as custodians of family health and hygiene.

8.3.4 Media

Media brings the insight of the story of the problem and often highlights the politics of the context. As stakeholders, members of the media can often have negative effects on water pollution management—largely by reporting only the sensational aspects of a given story. However, impartial and accurate reporting may also serve to bring stakeholders together by, for example:

- Identifying the core issue for the public and the responsible parties;
- Allowing unheard voices to be heard (virtual participation);
- Facilitating common ground among the stakeholders;
- Ensuring transparency; and
- Sharing documentary evidence.

UN PHOTO/VIOLAINE MARTIN

Public perceptions are informed through numerous media channels, hence delivering messages through the media can be effective in reaching a broad regional, national, or international audience. News focuses public attention and conversation, reaching policymakers and elected officials. When using the media as a means to build awareness of water quality issues, it is essential to provide interesting visuals, share key research statistics and conclusions, and discuss potential or in-development solutions.

8.4 STAKEHOLDER PARTICIPATION AND COORDINATION

The implementation level of activities targeting stakeholders varies based on their primary role in water pollution management processes and contextually driven tasks and functions. For instance, national coordination is required in setting water quality objectives and standards, while water body monitoring can be accomplished with local level participation. While wide coordination is essential to maintain open communications and insure transparency by sharing information, certain practical tasks require limited stakeholder engagement.

Stakeholder management is a delicate process (see Box 8.2). Care should be taken to maintain a cooperative group spirit, as not all participation is of a desirable nature (see Table 8.2). Several broad guiding principles can help achieve active and consistent stakeholder participation in water pollution management, such as:

- Build trust and support for the process of water pollution management;
- Share responsibility for decisions or actions (e.g. in monitoring water quality);
- Discuss and agree on the roles and responsibilities of each stakeholder or group;
- Establish stakeholder participation structures (e.g. monthly meetings, online message boards, suggestion boxes);
- Clarify and promote benefits of participation; and
- Customize stakeholder communications channels, content and language (see Box 8.3).

BOX 8.2 CHALLENGES IN STAKEHOLDER PARTICIPATION AND COORDINATION

- **Decreased stakeholder interest and involvement over time**
- **Varied levels of education and social status (stratification by gender, cast, minority, marginalized group)**
- **Different social and cultural values**
- **Time-consuming stakeholder processes**
- **Communication barriers**
- **Excessive or unbalanced stakeholder loads**
- **Inadequate funds and other resources**

DISCUSSION QUESTION

What would be the most effective methods of reaching and engaging victims of water pollution in your country?

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BOX 8.3 COMMUNICATING EFFECTIVELY WITH TARGETED STAKEHOLDER OUTREACH

When operating on a national scale, effective management requires targeted outreach. Planning such outreach should begin alongside the initial stakeholder mapping that identifies key groups.

Beyond their level of engagement or importance to water pollution management, stakeholders vary greatly in socio-economic characteristics—with differences in income, education, awareness, and access to public services and facilities of particular relevance to the outreach effort. Planning stakeholder outreach must account for such differences when selecting communications channels, content and language.

Communications channels including email, digital file dissemination (e.g. sharing or making PDF files available for download) and interactive websites work well for government, media and academic stakeholders, whereas the same tools would not reach many in the victim stakeholder group—the rural and urban poor, indigenous and nomadic communities and others who lack Internet access. Engaging these stakeholder segments requires field visits by development practitioners or community mobilizers, often with a considerable investment in relationship-building and educational activities. Flyers, handouts and local signage (e.g. billboards, posters) are effective supporting communications tools in the poorest rural communities; television offers an option for reaching some of the urban poor via public service announcements.

Content and language should also vary according to audience characteristics. Content should, first and foremost, remain transparent and be widely shared to the extent practical or useful (i.e. a published report is of little use to an illiterate individual). At the same time, content targeted at a particular group should prioritize that group's issues and concerns. Victims want to discuss compensation and prevention, whereas those holding discharge permits will be more interested in the rationale for fee structures. Also, top business executives and politicians require sophisticated but very brief presentations. Brevity is of equal importance with the least educated and highly marginalized communities; local literacy rates can shed light on the needed simplicity of language and whether victim outreach would benefit from a more visual approach (e.g. illustration, photography). Media outreach is likely to need carefully crafted content to balance journalist ambitions with thorough and balanced water quality information. Academic and financial stakeholders require a very high level of technical detail and material sophistication, with possibly non-trivial publishing costs (e.g. donor reports, research findings).

TABLE 8.2 STAKEHOLDER PARTICIPATION TYPES

TYPE	CHARACTERISTICS
Manipulative participation	Participation is simply presence. E.g. local level awareness programme
Passive participation	People participate by finding out about decisions and actions after the fact. Information is shared only among professionals. E.g. education and training programme
Participation by consultation	People answer question but do not participate in decision-making. Professionals are under no obligation to consider the views shared. E.g. interviews, community meetings, questionnaires
Participation for material incentive	People participate in return for food, cash or other material incentives. Local people have no stake in sustaining underlying practices when incentives end. E.g. compliance monitoring processes
Functional participation	Participation is seen by external agencies as a means to achieve project goals, particularly reduced costs. People may participate by forming groups to meet predetermined project objectives. E.g. local level environmental groups (meetings, group action)
Interactive participation	People participate in joint analysis that leads to action plans and the formation or strengthening of local groups or institutions that determine how available resources are used. A learning method is used to seek multiple viewpoints. E.g. setting effluent quality standards, local mobilization for water pollution management
Self-mobilization	People participate by taking initiative independently of external institutions. They develop contacts with external institutions for resources and technical advice but retain control over how resources are used. E.g. making a complaint to a local committee; filing a legal case; mobilizing community action

Source: Pretty 1997.

MAINTAINING ACTIVE PARTICIPATION

Despite the long and difficult process of mobilizing and organizing stakeholders, the largest challenge is maintaining their active participation over time. For many stakeholders, water resources management seems to be an extremely negative subject, as they are suddenly faced with higher bills, restriction of water abstraction activities, and effluent charges or demand for self-monitoring. Proactive measures help balance stakeholder concerns and maintain active participation.

For many stakeholders, water resources management seems to be an extremely negative subject, as they are suddenly faced with higher bills, restriction of water abstraction activities, and effluent charges or demand for self-monitoring.

Guidelines for promoting active stakeholder participation include:

- **Institutionalize stakeholder participation.** To ensure its legitimacy, stakeholder participation at different levels (tributary, sub-basin and basin) has to be mandatory and legally recognized. The optimal arrangement is for basin-level IWRM plans to fully encompass water quality management, including the status, rights, roles and responsibilities of relevant stakeholders.
- **Share information often**. Information is critical to retaining stakeholder interest and fostering local ownership. There is a wide variety of information-sharing and dissemination tools, ranging from meetings and workshops to information leaflets, websites, field visits and others. Regulators bear the responsibility of implementing and ensuring the operating efficiency of mechanisms for ongoing stakeholder communication regarding the status of water pollution management activities (e.g. periodic meetings, newsletters).
- **Build stakeholder capacities.** Stakeholder participation is often hampered by lack of capacity (e.g. education, social status). While there is value and knowledge to be gained by engaging with all stakeholder groups, some may require considerable capacity-building support. Empowerment is a key element to increase the effectiveness of stakeholder participation (e.g. training in negotiation, communications, and technical aspects of pollution management or water quality monitoring).
- **Assign responsibilities and clarify roles.** Without clearly defined roles and responsibilities, sustained stakeholder participation is unlikely. At the same time, the limitations for fulfilling the responsibility also should identified and rectified to ensure the relevant roles are assigned.
- **Maintain focus on positive outcomes and participation benefits.** Fostering stakeholder enthusiasm and hope can only have positive effects. To maintain momentum, it is useful to remain focused on attaining the expected positive outcomes for human health, ecosystems and attainment of broader national development goals.

DISCUSSION QUESTIONS

How far has stakeholder participation been taken in present interventions of your country? Which stakeholders do not participate and why?

KEY MESSAGES

- **The wide range of stakeholders can be categorized into five groups: polluters, victims, regulators, financial and implementing partners, and interested observers.**
- **Stakeholder analysis helps identify the most influential and important stakeholders. The victim stakeholder group tends to be the most marginalized and least influential; it is critical to engage representatives of pollution-affected communities.**
- **Maintaining active stakeholder participation is important to balance stakeholder concerns and requires effective communication and coordination.**

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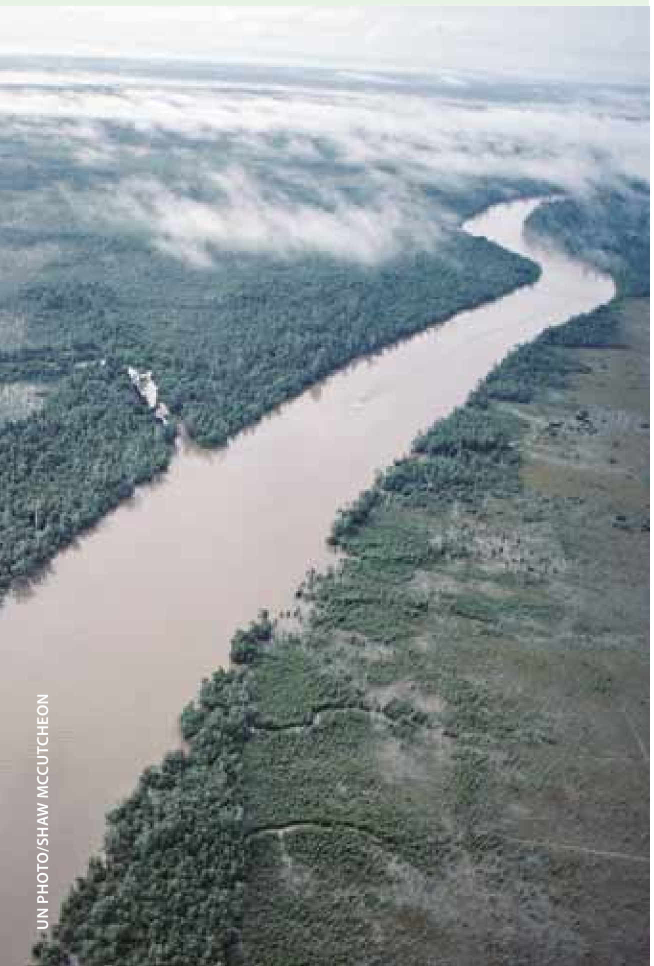
LEARNING OBJECTIVES

In this module, participants will learn to:

- **Understand the process, need for and approaches to water pollution licensing;**
- **Understand different methods for licensing point source pollution;**
- **Understand different ways of regulating non-point source pollution; and**
- **Understand ways of enforcing permit conditions and improving compliance by permit holders.**



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MODULE 9

Water pollution licensing

Licensing is important in the prevention, control and reduction of water pollution and its adverse impacts on human health and aquatic ecosystems. A licensing strategy is implemented through regulations that control pollution of water resources. Such regulations, commonly referred to as **wastewater discharge regulations** or **water pollution control regulations**, have provisions for issuing permits with accompanying conditions to any activity that may pollute water or land. Standards are set by regulatory agencies, as discussed in Module 6. People and entities granted permits have to ensure that their effluent discharges conform to the standards—or be penalized.

DISCUSSION QUESTION

Who should be licensed?

UN PHOTO/MARK GARTEN

9.1 WATER POLLUTION LICENSING PROCESS

In order to identify, plan and implement the most appropriate regulations and control measures, the pollution licensing process must begin with understanding the sources and types of pollutants typical to the local context by conducting a pollution inventory. Licensing decisions and other management action should be a function of the significance of identified water pollution problems.

The licensing progress proceeds once sources and types of pollution are assessed and water quality is found to be significantly below acceptable levels. In situations where pollution causes risks to human health, an environmental audit can help assess the impact of the pollution in detail to inform setting appropriate permit conditions. When a country's water sector institutions are new and yet to become operational, an environmental impact assessment conducted in the early planning stages can help identify potential environmental impacts and recommend mitigation measures.

Information obtained from pollution inventories and concurrent environmental audits and assessments, if any, underpins water pollution regulations. The standards must be attainable and non-compliance charges affordable but high enough to deter damaging action—and be perceived as such by the licensed stakeholders. Regulations should employ best environmental management approaches and a contextually appropriate mix of end-of-pipe and process-based techniques to control point source and non-point pollution.

9.2 POLLUTION INVENTORIES

Pollution inventories aim to obtain information on pollutant sources and types, and usually include reports on the amount of pollution actually observed and the results of pollution surveys. **Substance inventories** focus on specific pollutants (e.g. pesticides in agricultural run-off), **environmental risk assessments** involve classifying new substances as potentially posing environmental or health hazards, while **input inventories** assess the quantities and types of pollutants discharging into a particular watercourse or aquatic body.

9.3 ENVIRONMENTAL AUDITS AND IMPACT ASSESSMENTS

In situations where there are plans for new establishments that may be sources of pollution, an environmental impact assessment can help assess planned discharges and potential impacts.

Once inventories are completed, it may be necessary to undertake environmental audits to assess the impacts of the polluting establishments on water resources. These audits provide a good basis for initiating the permit process, should they indicate local water resources are being polluted. In situations where there are plans for new establishments that may be sources of pollution, an environmental impact assessment can help assess planned discharges and potential impacts. If it indicates there is potential for pollution of water resources, regulators may impose requirements on the new establishment to reduce the potential pollution and to operate within the bounds of a specific permit.

9.4 REGULATING POINT SOURCE POLLUTION

The key characteristic of point source pollution is that it is identifiable and can, therefore, be monitored and controlled. Regulation of point source pollution entering the aquatic environment can be carried out in two ways: end-of-pipe controls and process controls.

End-of-pipe regulation involves controlling what is released from a discharge point, with little or no control of the processes that produce the effluents. In contrast, process control regulation parallels the production process and aims to minimize its resulting impact on the environment by minimizing the effluent generated by the process as a whole. One or both of these techniques are currently used, depending on the legislative system in place. For example, the United Kingdom has used both systems for many years, with the end-of-pipe technique used to regulate discharges to water bodies and the process-based technique used to controlling discharges to the atmosphere and land. At the same time, developing countries more commonly use the end-of-pipe regulation technique.

9.4.1 End-of-pipe techniques

Many countries require permits for the discharge of sewage and other effluents into water, subject to meeting quality standards. Water quality standards are derived for a large number of substances and are used to assess the impact of industrial discharges on particular watercourses in order to ensure that the constituents of the discharge do not pollute water resources. In this case, there is a presumption that the discharge of polluting matter into watercourses is illegal—unless specifically permitted.

Therefore, any establishment that discharges effluent has to obtain a permit to avoid breaking the law. The permit is issued upon application to the appropriate regulatory body, which takes into account the set standards. In urban areas connected to municipal sewers, trade effluent is rarely discharged direct to a watercourse but is instead treated by the local sewage utilities. Water pollution management is therefore achieved by issuing a permit for the discharge to the sewage utilities, including the prescribed composition of trade effluents discharged to the sewer and, eventually, to water bodies. In turn, the sewage utility holds a permit for the discharge of the treated wastewater to the local water body. The regulator does not take an active part in controlling the industrial wastewater pre-treatment process.

In urban areas connected to municipal sewers, water pollution management is typically achieved by issuing a discharge permit to sewage utilities, including the prescribed composition of trade effluents discharged to the sewer and, eventually, to water bodies.

Industrial wastewater dischargers are often required by water utilities to provide and operate their own pre-treatment plants to treat pollutants that pass through or affect municipal works or the sludge produced. This approach reduces the number of permits a regulator has to issue and monitor for compliance, thus cutting down the workload and the cost. Where there is no sewer system, regulators have a much greater workload, as industries large and small have to be identified, licensed and monitored for pollution control to be effective.

ISSUANCE OF WASTEWATER DISCHARGE PERMITS

A wastewater discharge permit is a tool used for end-of-pipe regulation to control pollution of water resources by wastewater. Issuance of the permit involves multiple stages.

Completion and submission of permit application forms

Based on the Ugandan experience, procedures followed in completing and submitting applications for wastewater discharge permits include:

- Applicant obtains application forms from the Directorate of Water Resources Management (DWRM) or from the Ministry of Water and Environment website.
- The permit application form is completed in triplicate.

BOX 9.1. TYPICAL CONTENT OF A WASTEWATER DISCHARGE PERMIT APPLICATION

- **Names and addresses:** details about the applicant;
- **Land related to this application:** details of the land where the works and use of the water will occur;
- **Source of water and purpose of water use:** description of the source of water from or to which the applicant wishes to take water and of the specific location where the water is or will be taken;
- **Nature of the discharge:** an indication of discharge content (e.g. sewage effluent, trade waste, emergency discharge of sewage effluent, contaminated surface water);
- **Means of discharge:** description of effluent delivery method, such as pipe, channel, borehole, soak-away pit, well, culvert or sub-irrigation system;
- **Technical details of the discharge:** details of the means of discharge of the effluent;
- **Recipient water body or system:** description of the water body to which waste will be discharged directly or indirectly (e.g. river or stream, surface or groundwater system, lake or pond, canal, land and water course);
- **Sampling of the discharge:** the means of sampling the discharge;
- **Other information:** background details such as the required duration of the permit, anticipated date of discharge commencement and historical considerations (e.g. whether an application addresses existing discharges, availability of existing discharge consents); and
- **Declaration by the applicant:** applicant confirmation of the information in the application (i.e. applicant signature and stamp).

- The applicant is issued a Bank Payment Advice Form for use when paying permit application fees.
- The permit application fee is a flat rate that covers the costs of evaluation and assessment of a water permit application.
- Upon confirmation of payment by the bank, the revenue authority issues a receipt to the applicant.
- The applicant submits the receipt and completed permit application forms to the Director of DWRM.
- Upon DWRM receipt of the application forms, one copy is acknowledged by stamping and returned to the applicant as confirmation of receipt.
- From the point of receipt, the application undergoes review and assessment before a permit is issued. This process may last up to 90 days, depending on the nature of the nature of the effluent and the availability of the required data and information about the discharging establishment.

See Box 9.1 for sample contents of an application form for a wastewater discharge permit.

BOX 9.2 ASSESSING WASTEWATER DISCHARGE PERMIT APPLICATIONS

Applications are assessed on a case-by-case basis as a function of effluent composition and nature. Key issues to be considered include:

- **Existing and projected quality of water in the receiving water body and downstream;**
- **Anticipated adverse effects of the discharge on existing authorized water uses, possible future beneficial water uses, the aquifer or waterway (including the effects on the land that shapes the waterway or its surroundings), in-stream water uses, the riparian environment and drainage regime;**
- **Minimum water quality and effluent discharge standards in place;**
- **Existing guidelines or conditions relating to wastewater discharge permits;**
- **Government policy on environmental management and conservation;**
- **Public feedback on the application gathered within at least 30 days of the date of the public notice requesting comments;**
- **Comments of the public authorities to which an application is referred for review and comments; and**
- **Any other matter that the management of the permit-issuing institution considers relevant to the application.**

Assessment of permit applications

Upon applicant completion and submission, a permit application should undergo office and filed-based assessments. An office assessment involves verifying provided information and making a preliminary evaluation of the request. A field assessment is then completed to further confirm applicant-provided information and take some field measurements and samples—of the effluent and the receiving water body—for laboratory analysis, in order to establish baseline conditions.

Application assessments should encompass all relevant issues, ranging from water quality (both current and projected based on the discharge that is the subject of the application) to public feedback on a specific application or polluter (see Box 9.2).

Setting rates and conditions for wastewater discharge permits

Charges vary depending on pollution loads and are designed to impose very severe penalties on wastewater discharges with excessive pollution. Of particular note is a condition to pay annual wastewater discharge fees based on the biological oxygen demand (BOD) load (concentration x discharge). Charges based on BOD are an economic instrument aimed at changing polluter behaviour and a direct application of the polluter-pays principle, where the polluter covers the full costs of the pollution. Such charges aim to encourage reduction of pollutant concentrations in wastewater and improve environmental conservation.

Wastewater discharge permits are issued with standard and special conditions. Standard conditions stem from the law and apply to all permit holders, irrespective of their location or effluent nature. Special conditions are specific to the applicant and depend on the type of pollutants being discharged and the environment of the applicant's location. (See Boxes 9.3 and 9.4.)

Annual charges are levied on water permit holders for the duration of their permits and are typically comprised of:

BOX 9.3 KEY CONDITIONS OF WASTEWATER DISCHARGE PERMITS

A wastewater discharge permit obligates its holder to:

- **Not cause or allow any water to be polluted;**
- **Prevent damage** to the source from which water is taken or to which water is discharged after use; and
- **Take precautions** to ensure that no activities on the land where water is used results in the accumulation of any substance that may render water less fit for reasonable existing or future uses.

An authorized representative may enter the land governed by the permit in order to:

(a) **inspect** works or water uses; or

(b) **take samples or conduct tests** to find out whether:

(i) water is being wasted, misused or polluted;

(ii) the terms of any waste discharge permit are being complied with; or

(iii) an offence is being committed against permit conditions.

Unless specifically authorized within a permit, persons or entities commit an offence when they cause or allow:

(a) waste to come into contact with any water than the allowable limits specified in the permit;

(b) waste to be discharged, directly or indirectly, into water; and

(c) water to be polluted.

A person or entity contravening permit provisions and thus causing damage is liable for the cost of **remedying such damage and rehabilitating the environment to pre-impact conditions**.

The owner or occupier of any premises governed by a wastewater discharge permit has the **right to discharge waste from the premises in accordance with permit terms and conditions for a specific period of time** (e.g. three months from the date of initial occupancy). After the expiry of the permit period, the management of the issuing authority, upon receipt of an application, typically grants a new permit, with conditions that are not more onerous to the applicant than those attached to the previous permit for the same premises—provided that the purposes for which such premises are used and the nature of waste do not change in any material respect.

Similarly, an authorized regulator may decide that, in order to make water available for a public purpose, it is necessary to cancel or adjust a specific permit. The director of **the permit-issuing authority or institution may, at any time, amend the terms of, suspend the operation of or revoke a wastewater discharge permit** if he or she deems it necessary to protect the environment or prevent water pollution.

- A flat rate to cover the costs of administrative procedures associated with issuing wastewater discharge permits and monitoring compliance to permit conditions; and
- A variable charge based on the specific type and quantity of pollutants being discharged.

DISCUSSION QUESTION

How would a permit system work in a city where most people do not have sewerage—does everyone obtain a permit?

BOX 9.4 UGANDA: WASTEWATER DISCHARGE PERMIT CONTENT

Name:

Permit Number:

1. Location of point of waste discharge

Basin:

Catchment:

District:

2. National grid reference for point of waste discharge

Latitude *Longitude*

3. Description of discharge

Numbers of existing discharges:

Type of discharge:

Nature of discharge:

Means of discharge:

Water body to which waste is discharged: *River or stream*

Maximum instantaneous rate of discharge should not exceed: *l/sec.*

Volume discharged shall not exceed: *m3/day in a period of 24 hours*

BOX 9.5 SAMPLE WASTEWATER DISCHARGE PERMIT

WASTE WATER DISCHARGE PERMIT
In accordance with the ____________ [title of waste discharge regulation]

In exercise of the powers conferred upon the Director by sections ________________ of the _______________; and in accordance with regulation ____________ of the [title of waste discharge regulations], this is to grant a Wastewater Discharge Permit.

Number: ____________

To: Discharge waste in accordance with the terms and conditions of this permit.
The permit is granted in the terms and conditions set here in the Annex, which is part of this permit, and under all other terms and conditions set in the [title of water statute], [title of waste discharge regulations] and [title of water resources regulations].

This permit is granted for a period not exceeding ___ year(s), which come into force on **Day, Month, Date and Year** until **Day, Month, Date and Year**.

Issuance Date: **Day, Month, Date and Year**

Printing and issuing permits

Once application assessment is completed and recommendations for permit issuance and conditions are made and approved by the responsible officer, a water permit is printed in hard copy. In addition, the permit document must be endorsed by a legally authorized person, which typically takes the form of applying an official seal that proves authenticity. The permit is then physically issued to the applicant, who signs it to ensure that it does not land in someone else's hands—and to preclude claims of not having received the permit (see Box 9.5).

BOX 9.6 PERMIT ENFORCEMENT MECHANISMS

- Written warning letters
- Regulator notices to permit holders requiring corrective action
- Compliance agreements with monitoring and enforcement plans
- Permit revision or cancellation
- Fines, administrative orders and economic sanctions
- Closure orders
- Prosecution through a court of law

Enforcing permit conditions and underlying laws can only be effective with the support and cooperation of national authorities, including the police and the judicial system.

ENFORCING WASTEWATER DISCHARGE PERMITS

Notably, permits should address their holders' responsibility for gathering data and information to be used for compliance monitoring. Regulatory agencies must be able to access and verify such data to inform decision-making and subsequent action. Regulator ability to take enforcement action against dischargers when permit conditions are breached is a key issue in point-source discharge regulation.

Typical regulatory and enforcement tools include fines, taxes, penalties and permit or license withdrawal (see Box 9.6). Although legal provisions vary widely among countries, all national laws permit regulatory action, such as prosecution through the courts at a minimum. Many mechanisms allow less severe action to be taken before criminal sanctions. It is therefore necessary to progressively move from notification (e.g. notices, reminders) to enforcement (e.g. fines, taxes, penalties and permit withdrawals).

A partnership approach to relations between the regulator and the regulated community is much more productive than policing. For example, some countries use a system of agreements, in which regulators issue informal notices requiring offenders to complete certain work to bring their discharge into compliance—although this is not a legal measure. A formal notice of permit violation may also be issued. In more extreme situations, regulators may issue a prohibition notice requiring the polluting activity to stop. Finally, legal action can be taken.

Enforcement of laws and regulations is a considerable challenge, globally. The functional effectiveness of regulatory and enforcement agencies depends on their flexibility and the involvement of various stakeholder groups, particularly local authorities and communities. In some countries, regulators have the power to close a business entity that is contravening pollution regulations. However, an enabling environment remains the most important issue for regulation enforcement (see Box 9.7).

BOX 9.7 PRIORITY ISSUES FOR REGULATORY AND ENFORCEMENT AGENCIES

- **Sufficient staff of adequate capability to enforce regulations and appropriately assess water pollution management needs;**
- **Practical and enforceable laws based on proven knowledge of water resource management and environmental impacts of use;**
- **Management and scientific expertise in water pollution prevention and environmental conservation;**
- **Stakeholder ownership of monitoring, enforcement and regulation procedures, to be built through awareness-raising and participatory management;**
- **Financial transparency and adequate resources to minimize regulatory failures and support staff and operations;**
- **Meaningful indicators and appropriate benchmarks for technical, economic and social issues; and**
- **Legal education and awareness-building among regulating parties and the public at large to put legal instruments into broad practice and ensure their use is not limited to specialists.**

MONITORING COMPLIANCE TO PERMIT CONDITIONS

Availability of data from monitoring and inspection visits is a prerequisite to wastewater discharge permit enforcement. Routine effluent sampling, laboratory analysis and reporting are the commonly used means of monitoring compliance. Promoting self-monitoring by permit holders provides data beyond that required by the regulator and, more importantly, ensures that permit holders take sufficient interest in their own effluent systems. Self-monitoring requires permit holders to take, examine and report on their effluent samples. Regulator follow-up and monitoring are necessary to ensure that self-monitoring data is accurate.

Sampling regimes must be established and recognized by permit holders as an important part of water quality control and effluent discharge regulations. This process should include defining the number and frequency of samples to be taken (daily, weekly, monthly or yearly) based on the size and nature of the discharge and the sensitivity of the receiving watercourse. Regular unannounced site inspections to examine the works and the discharge are an effective means of monitoring permit compliance.

Compliance monitoring can also provide broad-based information about the progress towards achieving project objectives. Data collected for enforcement can therefore be used to judge whether the project was sufficiently planned and implemented. Compliance monitoring can also be used for forward planning by identifying shortfalls that need correction by further investment or through improved operating procedures.

9.4.2 Process-based regulation techniques

The alternative—or an addition—to end-of-pipe regulation is to authorize the process itself. Process regulation aims to control water pollution by reducing or eliminating contaminants at the source. This technique can be effective but requires a broad and thorough understanding of production processes, which may be challenging in developing country economies.

Process-based pollution prevention strategies should aim to reduce or eliminate the use of hazardous substances, pollutants, and contaminants; modify equipment and technologies to generate less waste; and reduce fugitive releases. The main objectives of process-based regulation are:

- To prevent or minimize the release of dangerous toxic substances and to render harmless any such substances that are released; and
- To develop an approach to pollution control that considers discharges from industrial processes in the context of their broad environmental impacts.

UN PHOTO/EVAN SCHNEIDER

A fundamental factor influencing the use of process-based regulation is the practical ability to reduce the amount of waste that must be discharged into the environment—or the difference among theoretical and practically achievable and affordable objectives. The advanced technologies required to implement process-based measures can challenge the financial and technical capabilities of developing countries. Consultation with general public and industrial stakeholders is essential to enable regulators to understand the impact of any proposed regulatory measures prior to setting water quality and effluent standards.

Cleaner production, zero waste and energy recovery exemplify the concepts underpinning process-based regulation. The approach—in line with the three Rs (reduce, reuse and recycle)—is very economical, as pollution prevention may be less expensive than end-of-pipe effluent treatment, particularly for large industrial businesses. Cleaner production is an integrated preventative environmental approach to processes, products and services to increase overall efficiency and reduce human health and environmental risks. Cleaner production generates less end-of-pipe effluent, leading to substantial financial savings to the discharger.

General public and regulated discharger participation are an important part of the point-source pollution regulatory regime. Such participation is essential to ensure that industry recognizes the need for, and accepts the obligations placed upon it by, the regulatory regime—and that the public is satisfied that adequate control is being exercised. Many countries have open arrangements, where all information, including internal communications, are available to the public.

The potential of and commitment to process-based regulation varies among countries, with the extent of a national sewerage system, particularly in urban environments, among critical distinctions. Compared to the almost 100 percent of the industrialized world, developing country sewerage coverage may be lower than 10 percent in urban areas. In an efficient sewerage system, the initiative to press for cleaner production and the challenges of compliance with environmental regulations lie with the operator of the sewerage treatment plant. In the absence of such a system, most industrial discharges go straight into drainage systems and groundwater, posing an enormous problem for regulators: a practical inability to identify and licence extremely large numbers of individual polluters in urban environments. To the extent possible, this process should be shifted to the municipal authorities that have the mandate to manage urban environments.

Process-related measures may also be applied in productive sectors such as agriculture, which is responsible for non-point source pollution. Mechanisms to reduce fertilizer and pesticide use (e.g. by pricing measures) have had demonstrable impact on non-point source pollution.

9.5 REGULATING NON-POINT SOURCE POLLUTION

Regulation of non-point source pollution relies heavily on collaboration and coordination with key stakeholder sectors of agriculture, urban and rural governments, and affected communities.

Non-point source pollution occurs when pollutants—in the form of silt, clay, chemicals, nutrients or toxic materials—wash over land, farmland, roadways, urban or suburban areas and into water bodies. Unlike point source pollution, non-point pollution management is faced with the challenge of identifying sources and subsequent operating difficulties with monitoring and controlling the pollution. A basin-level approach helps identify diffuse pollution in relation to land-use activities and pollution control policies and measures.

Effective management of non-point source pollution requires conducting an inventory of possible sources. Agricultural pollution source inventory should cover nutrients (nitrogen, phosphorous, other minor nutrients), pesticides (herbicides, insecticides, fungicides) and soil amendments (lime, gypsum). Urban environments require inventories of roadway runoff (oil, grease, silt, heavy metals) and urban settlement drainage (organic matter, microbial contaminants).

Regulation of non-point source pollution relies heavily on collaboration and coordination with key stakeholder sectors of agriculture, urban and rural governments, and affected communities. Best environmental practices are essential to minimizing non-point source pollution. For example, guidance could be provided on good agronomic practices, such as proper timing for land preparation and the type, amount and time of application for fertilizers, manure and pesticides. Partial or total bans on using or importing toxic chemicals can also be considered.

KEY MESSAGES

- **Licensing should initially target large-quantity dischargers responsible for the majority of pollution, moving to smaller dischargers progressively.**
- **Enforcement of water pollution legislation is more complex than discharge regulation alone.**
- **Regulating water pollution requires collaboration between dischargers and regulating and enforcement agencies.**
- **Self-regulation by dischargers is most useful when supplemented by monitoring and random sampling by the regulatory agency.**
- **End-of-pipe (e.g. wastewater discharge permits) and process-based (e.g. cleaner production) regulation tools are commonly used to control water pollution. Process-based regulation is viewed as more economical and logical, as it focuses on prevention; however, it may not be practical in all developing country contexts due to financing and capacity gaps.**
- **Water quality goals and standards should be technically achievable and supported by institutional capacity to monitor and apply them. Unrealistic standards may be too costly to apply and may reduce the credibility of the legislation, thus undermining compliance.**

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LEARNING OBJECTIVES

In this module, participants will learn to:

- **Understand monitoring systems and key objectives;**
- **Appreciate the need for monitoring in water pollution management;**
- **Understand the types of water quality monitoring networks;**
- **Appreciate and understand network design principles, monitoring frequency and key elements of monitoring systems; and**
- **Appreciate the mechanisms for effective water quality monitoring.**


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MODULE 10

Water quality monitoring systems

Monitoring comprises the ongoing collection, storage and analysis of data and information to support decision-making for effective water resources management. Information on water pollution is collected through coordinated water quality monitoring programmes, which require a lot of resources to ensure that monitoring is continuous and sustainable. An effective monitoring system is necessary to enforce pollution regulations and provide benefits for society as a whole; therefore, funding for monitoring should come from both government and polluting entities.

Monitoring objectives are set in line with the focus of water management and water pollution management activities, while also accounting for issues that capture public attention (see Box 10.1 for common broad categories). A monitoring objective, once defined, identifies the target audience, the users of information gathered and the necessity thereof. Objectives should also identify the field of management and the nature of the decision-making for which the information is needed.

DISCUSSION QUESTIONS

Does your country have a monitoring system that determines the quality of surface and groundwater? Are the results available to the public?

BOX 10.1 MONITORING OBJECTIVES IN WATER POLLUTION MANAGEMENT

- Compliance with quality standards: Assessment of water bodies by testing water for compliance with set quality standards for various water functions and uses
- Compliance with discharge permits or setting of levies: Assessment of wastewater or agricultural runoff for specific pollutants
- Verification of the effectiveness of pollution control strategies: Obtaining information on progress towards full implementation of agreed measures or monitoring data analysis to discern long-term trends in pollutant concentrations and loads
- Early warning: Observing and documenting change in a given aquatic environment to identify adverse impacts, such as accidental pollution
- Awareness-building: Providing in-depth data on water quality
- Decision-making support: Gathering information to broadly support the strategic formulation, planning, operations and management of water quality programmes or to validate a particular strategy or decision

BOX 10.2 CHARACTERISTICS OF A SUCCESSFUL MONITORING PROGRAMME

- Monitoring objectives are defined first and form the basis of the monitoring programme, not vice versa.
- Type and nature of the water body is sufficiently understood, through preliminary surveys at the minimum.
- Appropriate media is defined (water, particulate matter, biota).
- Critical monitoring choices and decisions are carefully linked to monitoring objectives—for example, when selecting the field, variables, sample types, sampling frequency, station location, laboratory facilities and analytical equipment.
- Data management scheme is complete and operational.
- Monitoring water quality of the aquatic environment is linked with hydrological and environmental monitoring.
- Data quality is regularly verified using internal and external controls.
- Data obtained is analysed to produce recommendations that inform decision-making and management action by appropriate actors.
- Monitoring programme is periodically evaluated to allow for course correction, such as in situations where a particular environmental influence has dramatically changed, either naturally or by measures taken at the basin level.

10.1 MONITORING SYSTEMS

Effective water quality monitoring is achieved when collected data is utilized to identify and solve a specific problem via corrective action. Thus, water quality monitoring information, corrective actions taken, inspections and assessment reports should all contribute to performance evaluation of monitoring systems. Monitoring and assessment should be integrated taking into consideration both quantity and quality and include media such as sediments and biota.

BOX 10.3 MONITORING SYSTEM IMPLEMENTATION AND OPERATIONAL CONSIDERATIONS

- **Identify decision-making and management information needs**
- **Assess financial and human capacity to maintain the monitoring system**
- **Design the monitoring programme and its implementation and operational routines according to meet defined objectives, such as data collection, handling, analysis, and management presentation and interpretation**

10.2 DESIGN AND OPERATION OF MONITORING NETWORKS

The key function of a network is to translate monitoring objectives into guidance as to where, what and when to measure. Network design, therefore, addresses sampling point locations, sampling frequency and the water quality variables to be measured. A central consideration during network design is that sampling stations, particularly those for baseline and impact monitoring, should be at, or close to, current hydrological recording stations or another location where the necessary hydrological information can be computed reliably. No meaningful interpretation of the analytical results of water quality assessments is possible without a corresponding hydrometric database. Other requirements for selecting station locations include accessibility, ease of sampling, safety for operators and samples' field-to-laboratory transit time.

Operational and compliance monitoring stations should be placed at the outlet of major municipal and industrial wastewater discharges. Point-source pollution monitoring requires substantial human resources and should be based on polluter self-monitoring—by, for example, municipalities and industries—supplemented by regulator monitoring inspections. Information needs, operating sustainability and a results-oriented programme design are important considerations (see Box 10.3).

Monitoring network design should be initiated by field surveys to identify potential water quality problems and water users, and by inventories of pollution sources to identify major loads. Monitoring programmes usually collect data from either biochemical water sample analyses or measuring equipment built into polluters' production lines. Available laboratory facilities, instruments, transportation and human resources restrict all monitoring programmes in some way, hence much data is primarily generated by direct sampling.

The complexity and size of the monitored area, the number of monitored pollutants and the monitoring frequency of all have to be balanced against available resources. The data gathered should support pollution management tools; for example, effluent standards enforcement can be facilitated by regulations requiring polluters to supply accurate and frequent data.

10.3 WATER QUALITY MONITORING NETWORK TYPES

Four types of water quality monitoring networks are commonly used. These differ in objectives and include: (i) ambient/basic; (ii) compliance; (iii) early warning; and (iv) operational or specific (see Table 10.1).

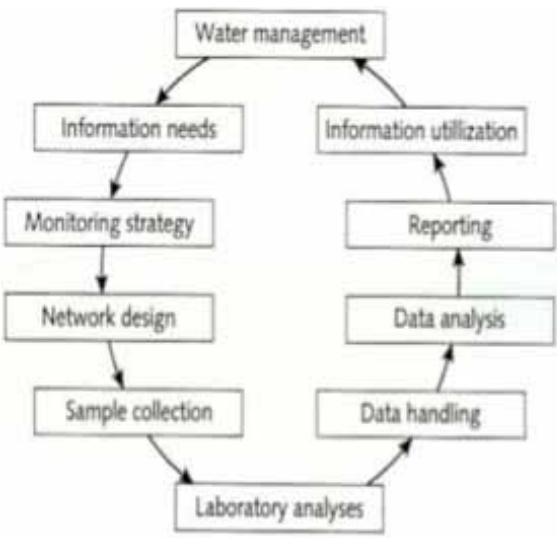
TABLE 10.1 WATER QUALITY MONITORING NETWORK TYPES AND OBJECTIVES

MONITORING NETWORK TYPE	MONITORING OBJECTIVE
Ambient (fixed sample points)	■ Status and trend detection ■ Testing of standards ■ Calculation of loads
Compliance (varied points according to permit holder location)	■ Quantifying and controlling effluent discharge ■ Monitoring plant performance against standards
Early warning (mix of fixed and varied points)	■ Disaster preparedness ■ Protection of downstream users and ecosystems
Operational (varied locations)	■ Operational monitoring (domestic water supply, irrigation and industrial uses, livestock and fishery uses)

CAP-NET

Based on existing resources and capacities, monitoring can vary in operational complexity. Simple monitoring involves a limited number of samples, simple analysis or observations and simple data treatment. Intermediate monitoring entails more variables and stations, and specific laboratory equipment and data handling procedures. Advanced monitoring involves sophisticated techniques, highly skilled personnel and complicated data handling processes. In all network types and complexity levels, the selected monitoring variables must adequately and non-ambiguously characterize the polluting effluent discharge or be representative of water bodies' functions and uses.

FIGURE 10.1 WATER QUALITY MONITORING CYCLE



Monitoring is a cyclical, ongoing endeavour (see Figure 10.1). Information needs evolve over time, hence the monitoring strategy should be regularly reviewed and adjusted as needed. Similarly, quality assurance and quality control of sampling and laboratory analyses should be conducted regularly to ensure that results are reliable and remain so.

10.3.1 Ambient/basic monitoring

Ambient or basic monitoring is the multi-objective long-term water quality monitoring of water bodies least likely to be affected by diffuse or point-source pollution and yielding natural or near-natural baselines, effects and trends. The monitoring parameters are based on environmental values and beneficial water uses, and are comprehensive enough to allow detecting trends at a particular site over time. Ambient monitoring data is regularly reported, widely accessible and—because ambient conditions are a national interest—most appropriately funded by the government.

SAMPLING AND MEASUREMENT

In considering the myriad water quality characteristics, it is necessary to select the monitoring parameters and frequency that are most relevant or important to the monitoring objective. Sampling and measurement costs and complexity should also inform such decision-making. The parameters typically sampled and measured from an ambient monitoring station include: Temperature, EC, pH, NO_2, NO_3, Total P, K^+, Na, Ca^{++}, Mg^{++}, CO_3^{--}, HCO_3^-, Cl^-, SO_4^{--}, COD, SiO2, F and B.

Monitoring programmes in areas with major industrial and agricultural pollution (in the form of heavy metals, pesticides or chemical fertilizers) require sampling of additional media, such as the sediment and biological material in which heavy metals and certain hazardous chemicals accumulate. In such cases, monitored variables typically include specific heavy metals and organic compounds.

MONITORING FREQUENCY

Sampling frequency is typically a function of station density, minimum data requirements and the number of monitored variables. Sampling frequency, the number of samples and the amount of monitored variables may have to be adapted to suit local resources, or to allow the necessary level of statistical analysis.

PARTICULATE MATTER SAMPLING AND BIOLOGICAL MONITORING

Monitoring programmes for particulate matter and biological material need careful design. In general, such programmes' sampling frequency is low compared to water sampling, but sample analysis is often more time-consuming. Monitoring of particulate matter, suspended or deposited on the bottom, is particularly important, because heavy metals and some hazardous organic industrial chemicals and pesticides are associated with the particulate matter and accumulate in deposited sediments, and water samples do not accurately represent pollution loads from such substances. Sampling can be performed with inexpensive grab or core samplers (for bottom sediment) and by filtration or centrifugation of water samples (for suspended material). Chemical analyses can be performed on extracts of the samples.

Monitoring of particulate matter, suspended or deposited on the bottom, is particularly important, because heavy metals and some hazardous organic industrial chemicals and pesticides are associated with the particulate matter and accumulate in deposited sediments, and water samples do not accurately represent pollution loads from such substances.

In addition to water quality monitoring, which benchmarks water quality at the time of sampling, biological monitoring can provide an integrated view of water quality over the lifetime of the selected fauna and flora. It is impossible to separately monitor the thousands of chemicals often occurring simultaneously in the environment, but biological methods can provide an indication of their combined effects. Consequently, biological monitoring has been introduced into many water quality monitoring systems.

DISCUSSION QUESTION

Do you have any examples of biological monitoring being implemented?

10.3.2 Compliance monitoring

Monitoring water quality is key in enforcing water pollution control measures. The purpose of compliance monitoring is to check for adherence to official water quality standards, guidelines, permits and contracts. Compliance monitoring is the responsibility of both regulators and holders of wastewater discharge or pollution permits.

Compliance monitoring can be direct, indirect or indicative. Direct monitoring measures the concentration of pollutants discharged into a water body, while indirect monitoring measures the water quality or ecological status of a downstream water body to infer the quality of the upstream body. Similarly, indicative monitoring measures the substances that contribute to water pollution, such as the pesticides or fertilizers used.

No single means of compliance monitoring is adequate by itself; direct, indirect or indicative monitoring methods can be employed together to address the demands of a specific pollution context. Direct compliance monitoring should be applied as self-monitoring, where discharge permit holders are required to measure, at their own cost, the specified parameters and report the resulting data to regulators on an ongoing basis. Regulator inspections, necessary to check the validity of self-reported information, should be irregular and unannounced.

BOX 10.4 KEY PARAMETERS FOR COMPLIANCE MONITORING

pH	**Turbidity**
Electrical conductivity	**Faecal coliforms**
Total suspended solids (105° and 500° C)	**BOD**
	COD
Dissolved oxygen	**Total nitrogen**
Temperature	**Color**
Total phosphorus	**Alkalinity**
Sodium	**Oil and grease**
Potassium	

SAMPLING AND MEASUREMENT

Routine effluent sampling alongside laboratory analysis and reporting is commonly used, in line with permits that contain provisions for specimen collection and sampling points. Most countries rely on self-monitoring to provide data beyond that required and, more importantly, to ensure that permit holders take sufficient interest in their own effluent systems as a result of being required to measure and report on a set of key parameters (see Box 10.4).

MONITORING FREQUENCY

Samples are typically taken over fixed time periods (daily, weekly, monthly, annually) and are measured relative to the size of the discharge, its nature and the sensitivity of the receiving watercourse. Consequently, sampling frequencies vary greatly—from once a day for larger discharges to once a month or less often for smaller ones.

10.3.3 Early warning or impact monitoring

Early warning or impact monitoring measures both water quality and the transport of pollutants in order to provide information on the impending pollution of water resources. Monitoring stations and networks are located downstream of current and possible future pollution sources, with additional monitoring stations placed upstream of water intakes to protect these in particular.

UN PHOTO/UNICEF/MARCO DORMINO

MONITORING FREQUENCY

The frequency of impact monitoring should reflect the variability and magnitude of the pollution load: the higher the volume, the more frequent the sampling. Direct monitoring of pollution loads from non-point sources is not possible; however, an impact monitoring station, located downstream of a catchment dominated by non-point sources such as agriculture, may be used for the evaluation of trends in loads from these sources.

10.3.4 Operational monitoring

Operational monitoring is carried out by service providers and users. It takes place in line with contracts, management procedures, system assessments, and design and operational regulations. The frequency of operational monitoring depends on the type, variability and quality of the effluent from each operational use (e.g. domestic water supply, irrigation, industrial use, livestock, fisheries).

KEY MESSAGES

- **An effective monitoring system is necessary to enforce pollution regulations and provide benefits for society as a whole; therefore, funding for monitoring should come from both governments and polluting entities. Related procedures can be simplified and costs reduced by involving stakeholders and using biological indicators.**
- **Monitoring objectives include ensuring compliance with standards or permits, benchmarking progress of specific pollution control measures, providing an early warning of impending pollution incidents, building awareness and supporting decision-making. Types of networks align with primary monitoring objectives and include ambient, compliance, early warning and operational.**
- **Compliance monitoring should take the form of permit holders self-monitoring wastewater discharges and regular reporting of the resulting data as a condition of such permits, along with spot regulator inspections. A feedback and information exchange mechanism between the regulators and permit holders should be developed and operationalized to improve motivation and sustainability of water quality monitoring.**
- **Water pollution monitoring should initially focus on high-risk areas and high-volume polluters.**
- **It is easier to monitor big polluters than small ones. Similarly, it is easier to monitor point-source pollution than non-point.**
- **Water quality should be monitored alongside water quantity to enable computation of pollution loads and further integrate water resources management.**
- **Water quality monitoring frequency should be based on monitoring objectives, the cost involved, and the available human and infrastructural capacity.**
- **Quality assurance and quality control of sampling and laboratory analyses should be conducted regularly to ensure that results are reliable and remain so.**

10.4 IMPROVING WATER QUALITY MONITORING

Effective water quality monitoring is driven by a specific objective. The data collected is used for operational management and systematically stored for future use. Although water quality monitoring is expensive, it is necessary, and its effectiveness can be improved by careful attention to:

- Monitoring network design and system implementation;
- Data management, interpretation and use;
- Accessibility of monitoring stations;
- Using indicator determinants to reduce analytical cost; and
- Participatory monitoring among water users.

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LEARNING OBJECTIVES

In this module, participants will learn to:

- **Appreciate how effective information management supports water pollution management;**
- **Understand information management processes and some of the tools used specifically in water pollution information management;**
- **Identify important water pollution information management outputs and their dissemination; and**
- **Integrate the ecosystem-based approach and the IWRM concept into water pollution information management.**

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MODULE 11

Information management

Effective water pollution management requires adequate, accurate, timely and essential data of various types and forms, continuously available from numerous different sources and locations. A systematic information management process is thus an important as part of water quality management in IWRM.

Under the IWRM-recommended basin-based approach, information management needs include:

- Identifying the key issues for water pollution management;
- Establishing water pollution information management objectives, for example:
  - Management of information for water pollution monitoring and risk assessment;
  - Provision of information outputs to support policymakers, decision makers, regulators, water managers, practitioners, water users and other stakeholders;
  - Dissemination of information on water pollution status for communication, education, public awareness raising, political commitment and public involvement;
- Prioritizing the data and information required to address key issues;
- Devising methodologies to obtain and analyse essential data and information; and
- Implementing management and reporting structures addressing what information is reported, how and to whom.

DISCUSSION QUESTION

Who should be responsible for water pollution information management of a river basin?

11.1 INFORMATION MANAGEMENT PROCESS


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Although human resources, technological and financial constraints can limit the ability to collect, store, analyse, interpret, use, share and disseminate information, the water pollution information management process should always comprise the key steps of information capture, storage, processing and use (sharing and dissemination).

11.1.1 Information capture

Water pollution management requires a reliable data set that provides an understanding of the water quality status. The first step is to decide on *what* the priority information needs are and *where* and *how* to capture the desired information.

The most basic expectation of information relevant to all stakeholders, including regulators and managers, will include:

- What is the present quality of surface and groundwater in my community, district and country?
- How has it changed from last year?

It is disappointing to note how often these two basic questions cannot be answered by a country's water authorities.

More information is needed in order to go beyond understanding water quality to actually managing it. Priority information or data to be included in the database or information system can be identified by information users, including water pollution managers, local authorities, water users, communities, relevant stakeholders and the public at large. Information required to address the most pressing issues of a river basin should be prioritized.

Priority information or data to be included in the database or information system can be identified by information users, including water pollution managers, local authorities, water users, communities, relevant stakeholders and the public at large.

Information, in forms of numerical, attribute, descriptive and spatial data, may describe:

- River basin, river network and associated ecosystems;
- Water quality objectives and guidelines for different uses;
- Major land uses;
- Water users and uses;
- Types and locations of pollution sources;
- Effluent quality standards and their reviews;
- Licensing records and license holder reports;
- Compliance and non-compliance records;
- Wastewater discharges/loadings;
- Water flow records;
- Effluent water quality;
- Records of complaints, queries, and water user and stakeholder reports;
- Sampling locations and descriptions; and
- Ambient water quality, including physical, chemical and biological parameters.

Extensive water quality data sets include data gathered through rigorous methods, such as:

- Intensive field surveys, scientific data and research;
- Ambient water quality investigations at various sampling sites;
- Effluent water quality investigations at sources or at various sampling sites;
- Networks of monitoring fixed stations distributing in sub-areas or sub-watersheds within the river basin; and
- Historical profiles obtained from participatory rural appraisals.

Information on surface and groundwater quality can be derived from field measurements and laboratory analyses. Water chemistry data usually reflects water quality at the sampling site and time, while bio-assessment and toxicant data reflects accumulated long-term effects.

Sustainable water pollution control and management requires a long-term data set and real-time water quality information. Continuity of data and information and consistency of laboratory methods are crucial for effective monitoring and comparative analysis. In this respect, the establishment of a monitoring system contributes a great deal to the database, with ambient monitoring providing the long-term information from a permanent set of sampling sites and compliance monitoring contributing operational information on the pollution management system.

11.1.2 Information storage

Irrespective of where and how, information should be stored in a user-friendly environment, ensuring ease of handling and access, security and protection from loss and damage over time and with contextual changes.

The *where* and *how* to store the defined and captured data and information can be simple or complex, depending on the desired levels of accuracy and timeliness of information, as well as technical and resource constraints.

Information can be stored in hard copies, paper files, record books and electronic media (such as flash drives, CDs and DVDs, computer hard disks and computer servers accessible by network users over the Internet). Information formats can range from simple text documents, tables, figures, photos, statistical records, information sheets and spreadsheets to more complex attribute and spatial databases or geographic information systems, including geo-referenced maps.

Data and information can be stored at various sources. Different agencies may store their own data sets; for example, hydrological data, water quality data and licensing records may be available from different sources. To bring together, effectively coordinate and manage such data and information, links should be established among different information sources. Cross-checking and verification is important, given that data conflicts may occur. Long-term storage and availability of raw data is equally critical, as methods of analysis and interpretation evolve continuously, and raw data is necessary to reprocess the information.

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Irrespective of where and how, information should be stored in a user-friendly environment, ensuring ease of handling and access, security and protection from loss and damage over time and with contextual changes. The level of security for each type of information or data can help group and store it accordingly. Open access should be made possible for approved users, while some conditions may apply to general public access in order to avoid data loss or inappropriate modification.

11.1.3 Information processing

Information and data must be entered and updated on a regular basis to ensure its up-to-date status and continuous availability. Update frequency and methodology should be a function of the frequency of water quality monitoring and data capture.

Information processing levels and methods are defined based on users' requirements and the desired information management outputs. The latter should be flexible to facilitate different assessment units tracking water quality in water bodies ranging from small streams to big rivers, from surface to sub-surface and groundwater, and from sub-watersheds to the overall entire watershed.

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Chosen information management tools and technologies should match available skills and resources to create reliable information databases and to facilitate information processing. For example, geographic information systems can help display, update, overlay and analyse spatial data linked to attribute databases. A geographic information system database can include a wide variety of information, such as locations of human settlements, distribution of land use activities, socio-economic data and pollution hotspots. Integration with Google Earth[51] can help continuously update spatial data captured from monitoring and generate maps for stakeholder review. Computer-based information management processes can help shorten turnaround times and facilitate effective water pollution monitoring, information analysis, assessment, management and forecasting.

11.1.4 Information uses, sharing and dissemination

The wide range of information users encompasses water managers, water users (including those who discharge waste and pollutants into water bodies), civil society (e.g. community-based organizations, NGOs, the media), government officials and political stakeholders. Different stakeholders have equally different information needs and thus require distinct dissemination methods and channels, which can range from comparatively simple and regular (monthly, quarterly, biannual or annual) hardcopy leaflets, reports, newsletters, graphic charts and maps to audiovisual materials, electronic media, CDs, DVDs, shared databases, and intranet or online platforms.

All stakeholders should be able to access regular status reports on water pollution in a river basin. A stakeholder information system should be put in place to facilitate making and responding to queries on water quality status, as well as making and addressing complaints.

DISCUSSION QUESTIONS

Who should determine the types of water pollution information to be collected and stored? What is the role of stakeholders in this decision?

51 See http://earth.google.com.

11.2 DATA ANALYSIS AND USE FOR MANAGEMENT

Different stakeholders have equally different information needs and thus require distinct dissemination methods and channels.

Stored data and information related to water pollution are mostly dynamic and variable (e.g. based on time or location). The types of data analysis that can be performed to address the various aspects and key issues of water pollution management include:

- Water quality status, classification and condition classes, and the need for water pollution control and management;
- Relationships among individual water quality parameters, and interactions between water quality parameters and other external factors;
- Factors affecting the ecological state, pressures and threats to water quality; threatened water bodies and associated causes and sources;
- Water quality risk factors;
- Water quality monitoring programmes for rivers, lakes, reservoirs, groundwater and associated wetlands;
- Water pollution trends and projections, particularly water quality changes over time (e.g. monthly, seasonal or annual variations), due to human activities and resulting from climate change; and
- Differences among sites/locations within a river basin and between different basins.

If the newly developed water pollution information database is linked with relevant modelling tools—including water quality and hydrological models—many additional useful data analyses can inform management and decision-making. Some examples include disaster preparedness assessments (addressing water pollution accident response), investigations of the effects of flow on pollutant distribution and ecological risk analyses.

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11.3 DEVELOPING INDICATORS

Appropriate indicators are entirely contextual and stem from both natural and man-made characteristics of a given basin.

Indicators fall into three groups: physical, chemical and biological. Physical indicators include water level or depth, surface area, temperature, transparency or turbidity, and total suspended solids. Chemical indicators are pH, conductivity, dissolved oxygen, BOD, COD, total phosphorus, total nitrogen, total nitrate and nitrite, and totals of some minerals, heavy metals and toxicants. Biological indicators address certain groups of diatom and phytobenthos, macrophytes, zoobenthos, faecal coliform, invertebrates, insects, amphibians, fish and other aquatic organisms.

Appropriate indicators are entirely contextual and stem from both natural and man-made characteristics of a given basin. Using the most relevant indicators to underpin communications with different stakeholder groups can ensure shared comprehension, improve stakeholder buy-in and ownership, and enhance overall communications effectiveness.

DISCUSSION QUESTION

How can indicators be used in pollution management?

11.4 INFORMATION MANAGEMENT OUTPUTS

Information sought by water pollution managers and other river basin stakeholder groups varies (see Table 11.1) and, as such, should be defined using participatory methods. Required information outputs should be made available and accessible in formats best suited to each user group.

TABLE 11.1 INFORMATION MANAGEMENT OUTPUTS BY TARGET GROUP

INFORMATION MANAGEMENT OUTPUT EXAMPLES	INFORMATION USER GROUP		
	GENERAL STAKEHOLDERS	WATER USERS	WATER POLLUTION MANAGERS
Leaflets or 'report cards' summarizing water quality information on a regular basis	✓	✓	
Annual reports summarizing water quality information (including surface and groundwater)	✓	✓	✓
Annual/seasonal/monthly/weekly/daily water quality reports (including surface and groundwater)			✓
Annual comparative reports against the basic set of water quality guidelines and standards or selected indicators, showing general trends over time	✓	✓	✓
Annual/seasonal/monthly/weekly/daily comparative reports against the basic set of water quality guidelines and standards or selected indicators, showing general trends of individual parameters or indicators over time			✓
Water quality indices and guideline values for different uses (e.g. drinking and domestic uses, aquatic life, agricultural uses, human impacts)	✓	✓	✓
Change detection over time and spatial differences between sites and between river basins based on analysis of water quality monitoring data from various stations up- and downstream			✓
Maps of water quality classification levels	✓	✓	✓
Maps of point-source pollution locations and relevant auxiliary information (e.g. loads, frequencies)	✓	✓	✓
Records of complaints, queries and reports of sudden changes in water quality by water users and stakeholders	✓	✓	✓
Records of license, permit, contract or regulation non-compliance by water users and corresponding management actions			✓
Water pollution guide providing information about sources and types of pollution, and how they can be addressed	✓	✓	

Source: Compiled from Cap-Net 2008 and MRC 2008.

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KEY MESSAGES

- Effective water pollution management requires adequate, accurate, timely and essential data of various types and forms, continuously available from numerous different sources and locations.
- Information to be collected, stored, analysed and disseminated should inform management and decision-making in areas of monitoring, policy planning, standard and guideline setting, and awareness-raising. The type of information captured depends on identified stakeholder needs. Appropriate indicators are entirely contextual and stem from both natural and man-made characteristics of a given basin.
- Information management should be systematic, up-to-date and long-term, while remaining realistic, manageable and usable in the context of available resources.
- Capturing, storing, processing and using (sharing and disseminating) information are the four key steps of the information management process.
  - Information capture methods include field surveys (sampling, measuring, observation), systematic monitoring, laboratory testing and analysis, research and historical data reviews.
  - Information storage may be handled by multiple actors but must be integrated for effective data cross-referencing, verification and analysis.
  - User requirements and the desired information management outputs define information processing levels and methodologies, with the chosen tools and technologies matching available skills and resources.
  - Information should be disseminated in formats best suited to different stakeholder groups.
  - Information outputs that meet the needs of water pollution managers and other stakeholder groups reflect the effectiveness of the overall information management strategy.

RESOURCES AND BIBLIOGRAPHY

Cap-Net. 2008. *Integrated Water Resources Management for River Basin Organizations. Training Manual*. http://www.cap-net.org/node/1494

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MRC. 2008. 'The Mekong River Report Card on Water Quality (2000–2006)'. Vientiane. http://www.mrcmekong.org/download/free_download/Water-Quality-Report-Card-2010.pdf

An example of public information materials: http://www.water-pollution.org.uk/

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ANNEX

Resources and references from UNEP work on water quality

The United Nations Environment Programme (UNEP) has a long history of championing water quality issues, ranging from promoting improved on-the-ground assessment and management to awareness raising at the policy level. UNEP's water quality work in collaboration with a range of partners is centred around a number of key initiatives, all of which are important for the monitoring and achievement of the Sustainable Development Goals (SDGs) of relevance to water quality; some UNEP initiatives go beyond SDG focus. This Annex briefly describes them.

UN-Water GEMI – Integrated Monitoring of Water and Sanitation Related SDG Targets

The GEMI initiative aims to integrate and expand existing global efforts to support harmonized monitoring and reporting of targets under SDG6 on water and sanitation. UNEP provides substantive support to the initiative, which includes water quality and reuse target 6.3: By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally. This target has two indicators: 6.3.1 – Proportion of wastewater safely treated, and 6.3.2 – Percentage of bodies of water with good ambient water quality. More information: http://www.unwater.org/gemi/en

UNEP Global Environment Monitoring System for Water (GEMS/Water) Programme

GEMS/Water provides support to global, regional, and national environmental assessment and reporting processes on the state and trends of surface and ground freshwater resources, through access to quality-assured data and information on water quality in freshwater ecosystems worldwide. Included in this work are efforts to:

- Strengthen and expand an extensive global network of data providers;
- Further develop and promote the GEMStat database water quality data sets collected from a global network (including close to 4.3 million records and over 100 parameters);
- Foster in situ, remote sensing and modelled data assimilation to improve geographical and temporal coverage of water quality information; and
- Provide capacity development support to further knowledge and skills for the monitoring and analyzing of water quality parameters at national, regional and global as well as institutional levels.

More information: http://www.unep.org/gemswater/Home/tabid/55762/Default.aspx

World Water Quality Assessment

The aim of this assessment is two-fold: First, to identify current and future problem areas of freshwater quality in surface waters, especially in developing countries; and second, to propose and evaluate policy options for addressing water pollution. The first phase results will be published in the second half of 2015. An integral part of this work involves:

- Reviewing the state of water quality in rivers and lakes/reservoirs especially in developing countries, with particular emphasis on public health and food security reflecting in the status of the freshwater fisheries;
- Identifying areas under serious threat by water pollution, now and over the coming decades;
- Identifying policy options that can be replicated and scaled-up to protect or restore water quality;
- Raising awareness of the importance of water quality degradation for local and national sustainable development; and
- Increasing the capacity of developing countries to protect or restore the quality of surface waters.

More information: http://www.unep.org/dewa/Portals/67/pdf/WWQA_24_March_2014.pdf

International Water Quality Guidelines for Ecosystems (IWQGES)

The aim of the IWQGES initiative is to develop a set of scientifically based water quality guidelines for ecosystems, enabling regional, national and local authorities to develop standards, policies and frameworks to improve the management of their water resources and aquatic ecosystems. These guidelines are intended to be global in scope and relevance, and assist, in particular, developing countries in their efforts to protect their aquatic resources. More information: http://www.unep.org/esm/Waterecosystems/WaterQuality/DevelopmentofIWQGES/tabid/131713/Default.aspx

UNEP/GPA Global Wastewater Initiative (GW²I)

Part of UNEP's Global Programme of Action for the protection of Marine Environment from Land Base activities (GPA), GW²I is a global multiple stakeholder platform comprised of UN agencies, international organizations, governments, scientists, private sector actors and other interested parties. The aim of GW²I is to initiate comprehensive, effective and sustained programmes addressing wastewater management. This is achieved by prompting synchronized action; encouraging investments in the field of wastewater; facilitating cooperation, coordination and synergy; and identifying and fostering opportunities that can be applied by countries and scaled up. More information: http://www.unep.org/gpa/gwi/gwi.asp

Development and dissemination of knowledge products together with expert partners

- **Policy brief on water quality:** This policy brief is a collaborative output of UN-Water members and partners directed at practitioners, policymakers and decision makers in water resource management and other relevant sectors. The policy brief outlines the challenges and trends, drivers and impacts related to water quality. It also presents four strategies that form the basis of policy solutions. It concludes by detailing a series of specific recommendations by which these solutions can be achieved. See http://www.unwater.org/downloads/waterquality_policybrief.pdf

- **Global compendium on existing water quality guidelines:** This compendium on existing water quality guidelines is a reference and resource tool for governments and stakeholders on how to incorporate water quality into water resource planning and management. The compendium also provides a platform for action, bringing together scientific, policy and management stakeholders to discuss how water quality levels can help address the increasing challenge of water-quality deterioration. See http://www.unep.org/esm/Waterecosystems/WaterQuality/GlobalCompendiumonexistingWaterQuality/tabid/131714/Default.aspx

- **Sick Water:** The central role of wastewater management in sustainable development. A rapid response assessment**:** This report identifies the main threats to human and ecological health and the consequences of poor wastewater management and degrading sewage systems. It also presents opportunities, where appropriate policy and management responses over the short and longer term can trigger employment, support livelihoods, boost public and ecosystem health and contribute to more intelligent water management. See http://www.unep.org/pdf/SickWater_screen.pdf
- **Clearing the Waters: A Focus on Water Quality Solutions:** This publication addresses the urgency of controlling pollution and preserving water quality around the world. Water quality impacts human health, water quantity, livelihood, economic activity, and climate change. Emerging contaminants, population growth and urbanization present additional stresses to water quality. This publication quantifies these water-quality related issues and uses case studies to illustrate both problems and solutions. See http://www.unep.org/PDF/Clearing_the_Waters.pdf
- **UNEP Live:** Water quality information provided by countries and global datasets and featured/mapped on the environmental information and knowledge management platform UNEP Live; this includes information on water quality and sanitation, access to sanitation and drivers influencing surface and groundwater quality such as fertilizer application, phosphate and nitrogen. Through the national reporting system UNEP Live will soon be enabling country based assessments and improve global and regional coverage of water quality information. For displays of data and maps, see http://uneplive.unep.org/
- **Water Pollution Control – A Guide to the Use of Water Quality Management Principles:** This is a handbook for policymakers and environmental managers in water authorities and engineering companies engaged in water quality programmes, especially in developing countries. It is also suitable for use as a textbook or as training material for water quality management courses. It is a companion volume to Water Quality Assessment and Water Quality Monitoring. See http://www.who.int/water_sanitation_health/resourcesquality/watpolcontrol.pdf

**INTERNATIONAL NETWORK
FOR CAPACITY DEVELOPMENT IN
SUSTAINABLE WATER MANAGEMENT
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