Chapter 3

Investing downstream in wastewater treatment and safe disposal

Providing safe access to water and sanitation generates significant benefits, as shown in Chapter 2. However, discharging untreated wastewater into the environment can affect users downstream (including population settlements, industry, agriculture etc.) and cause environmental damages. Collecting and treating wastewater and stormwater is required to ensure the long-term availability of water in a convenient quality for human use and environmental demands.[1] Despite its importance, it appears that investments in wastewater treatment are often below the required levels to generate sustained benefits.

In contrast to water supply and sanitation services, the benefits of wastewater treatment are less obvious to individuals (Wolff, 2003). The consensus on the need for increased urban wastewater treatment as well as safe disposal of its residues has therefore developed slowly (Rodriguez, 2009), probably also due to the relatively high costs of the proposed technologies (Jouravlev, 2004). In the United States, the 1972 Clean Water Act (CWA) built an important legal basis for expanding wastewater treatment facilities. In Europe, the European Union (EU) Urban Waste Water Treatment Directive (UWWTD) adopted in 1991 represented the policy response to the growing problem of untreated sewage disposed into the aquatic environment. The latter sets minimum standards for the collection, treatment and disposal of wastewater while considering the size of the discharge and the type and sensitivity of the receiving waters (Crouzet *et al.*, 1999). Despite these policy initiatives, the US still need major investments in wastewater treatment, to increase coverage and to maintain the performance of existing facilities. For example, the rating attributed to wastewater infrastructure by the US American Society of Civil Engineers (ASCE) had fallen from D+ in 1998 to D- by 2009, reflecting chronic under-investment.[2]

Wastewater treatment coverage is still limited in most parts of the world. In Latin America and the Caribbean, for example, it was estimated that only 13.7% of wastewaters discharged by the 241 million people connected to the sewerage network received some degree of treatment in 2004 (Jouravlev, 2004). This situation is common in many other developing countries, with even much lower levels of wastewater treatment or none at all: in Dar Es Salaam (Tanzania), for example, it is estimated that only 3% of wastewater is treated before being discharged into surface waters and the nearby sea.[3] The People's Republic of China has been investing massively in recent years to increase wastewater treatment coverage, going from 52% of wastewaters treated with secondary and tertiary treatment in 2005 to an estimated 60-65% in 2011 and projected to reach 70 to 80% in 2016.[4] In the following sections, the different types of wastewater treatment investments as well as technologies to safely dispose of the residual sludge are briefly described, before setting out the benefits of both in more detail.

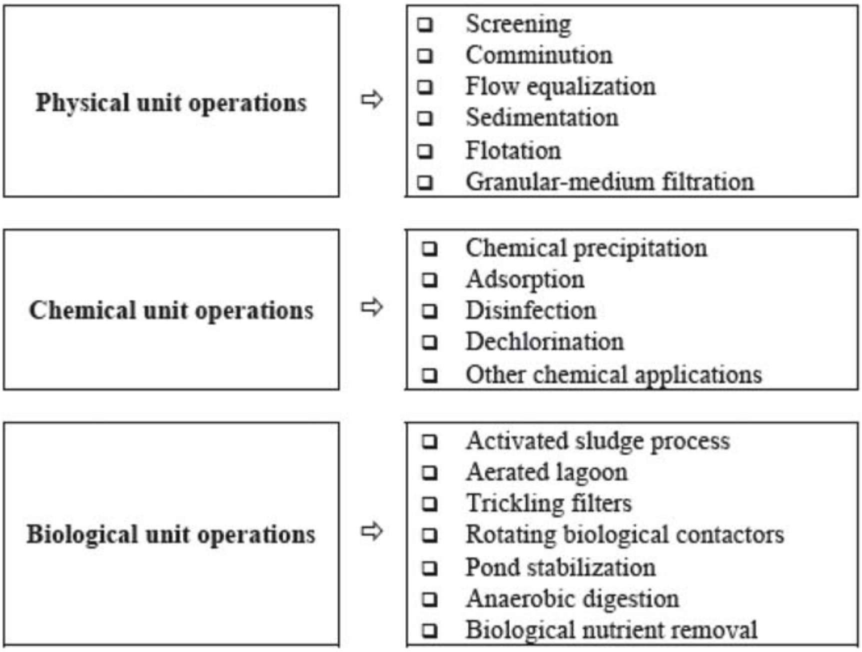
3.1 Investments in wastewater treatment

Untreated urban wastewater usually shows high content levels of organic material, various pathogenic micro-organisms, as well as nutrients and toxic compounds. The characteristics of sewage can be defined using physical, chemical and biological parameters (UN, 2003). Common indicators to describe the organic content of wastewater include for example the biochemical oxygen demand (BOD) which is a measure of the oxygen used for sewage decomposition (and which implies a reduction in the availability of oxygen for aquatic life) (Wilson, 2000). Furthermore, inorganic chemical parameters (*e.g.* concentrations of nitrates, phosphates or salinity) as well as bacteriological parameters can be used. However, all constituents and concentrations can vary with time and local conditions (UN, 2003). More or less complex treatment processes are applied to remove the different polluting substances from the water.

Depending on the level of treatment provided by the wastewater treatment plants, contaminants are removed through physical, chemical and biological processes (see Figure 3.1). The individual processes are grouped together in a variety of configurations for producing different levels of treatment. Based on this, wastewater treatment plants can be classified based on whether they provide preliminary, primary, secondary, tertiary and/or advanced treatment (UN, 2003).

Preliminary treatment removes bigger objects in order to prepare water for the actual treatment process. In the primary treatment process, mainly physical operations are used to remove a first part of the pollutants. Secondary treatment eliminates soluble organics and suspended solids with

Figure 3.1. **Wastewater treatment operations and processes**



Physical unit operations ⇨
- ☐ Screening
- ☐ Comminution
- ☐ Flow equalization
- ☐ Sedimentation
- ☐ Flotation
- ☐ Granular-medium filtration

Chemical unit operations ⇨
- ☐ Chemical precipitation
- ☐ Adsorption
- ☐ Disinfection
- ☐ Dechlorination
- ☐ Other chemical applications

Biological unit operations ⇨
- ☐ Activated sludge process
- ☐ Aerated lagoon
- ☐ Trickling filters
- ☐ Rotating biological contactors
- ☐ Pond stabilization
- ☐ Anaerobic digestion
- ☐ Biological nutrient removal

Source: United Nations (2003).

biological processes. In a last step, tertiary or advanced wastewater treatment removes significant amounts of nitrogen, phosphorus, heavy metals, bacteria and viruses, beyond the level of conventional secondary treatment (United Nations, 2003 or Wilson, 2000).

Comprehensive handling of wastewater does not stop with the treatment process alone, but has to ensure the safe disposal of residual sludge. As the residue of the wastewater treatment process, sewage sludge is rich in organic material, but potentially includes also hazardous substances like heavy metals, bacteria, viruses and different types of chemicals. Poor sewage sludge management practices can therefore result in risks to human health, water, air, soil quality and biodiversity. Different treatment processes affecting sludge composition can be applied prior to its disposal or recycling and thus reduce risks. The potential impact of sewage sludge depends furthermore on the way it is used afterwards. Whereas it is usually applied to agricultural land, some countries (*e.g.* UK) use increasing amounts in the forestry sector, and in former opencast coal sites for the purpose of land restoration (Ayres *et al.*, 2008).

In addition, natural systems can provide wastewater treatment services. In particular, those systems include land treatment and constructed wetlands (UN, 2003; EPA, 2000), of which the self-purification capacity reduces pollution. Reed *et al.* (1988, in: UN, 2003) emphasises that they can be the most cost-effective option in terms of construction and operation, in cases where sufficient suitable land is available. Constructed wetlands are often well suited for small communities and rural areas. For municipal and industrial wastewater, land treatment consists predominantly in the controlled application of wastewater to vegetated land. Natural treatment processes occur either when the water percolates through the soil profile or when it flows down a network of vegetated sloping terraces. Constructed wetlands, on the other hand, dispose of vegetation that "provides surfaces for the attachment of bacteria films, aids in the filtration and absorption of waste-water constituents, transfers oxygen into the water column, and controls the growth of algae by restricting the penetration of sunlight" (UN, 2003).

Wetland services can also be linked to a wastewater treatment plant. If so, they are particularly effective in taking over tertiary treatment processes. Kazmierczak (2000) mentions for example the importance of coastal wetlands for the mitigation of degraded water flowing south through the coastal Louisiana and the Northern Gulf of Mexico.

3.2 Benefits from wastewater treatment

Discharging untreated wastewater into the environment has manifold effects which depend on the types and concentrations of pollutants and the receiving environment (UN, 2003). To the same extent, the benefits of treating wastewater vary. Table 3.1 lists important contaminants in wastewater, their potential effects on receiving waters and treatment needs.

All benefits from wastewater treatment are linked to an improvement in water quality through the removal of different polluting substances. Different ways of classifying water quality benefits can be found in the literature (see also Atkins & Burdon, 2006). Dumas and Schuhmann (2004) are falling back on Feenberg & Mills (1980) when differentiating predominantly between withdrawal benefits and in-stream benefits. Whereas the former includes municipal water supply and domestic use benefits as well as benefits linked to irrigated agriculture, livestock watering and industrial processes, in-stream benefits arise from the water left "in the stream". The latter can furthermore be differentiated between use benefits (*e.g.* swimming, boating, fishing, but also stream-side trail hikers) and non-use benefits of water quality (including option value, bequest value and existence value).[5]

In the following paragraphs, the different types of benefits are presented, differentiating between: *(1)* health benefits; *(2)* environmental benefits;

(3) benefits for economic sectors; and *(4)* other benefits (*e.g.* recreational or aesthetic benefits as well as the impact on land and property values).

Quantifying benefits resulting from wastewater treatment is a challenging task. Firstly, the literature usually aggregates benefits from water quality improvements resulting from wastewater treatment plants and from other measures, such as enhanced agricultural practices. In a study undertaken by the US Environmental Protection Agency (Bingham *et al.*, 2000) the benefits of the water pollution control legislation in the last 30 years have been estimated to about USD 11 billion annually (about USD 109 per household). Those benefits include the impacts of the use of wastewater treatment plants; however, they cannot be singled out. Thus, it is rarely possible to assess the marginal benefits of wastewater treatment. Secondly, whereas improvements in water quality can take place continuously, this is not directly translated into continuously increasing non-use benefits. The water quality amelioration has to exceed a certain threshold (*e.g.* disappearance of unpleasant odours) before it can be recognised and valued by citizens. Furthermore, some improvements in water quality might not be perceived at all by individuals (*e.g.* linked to changes in dissolved oxygen content).

Table 3.1. **Main contaminants in wastewater and impact on receiving waters**

Contaminants	Effects on receiving waters and treatment needs
Suspended solids	Can lead to development of sludge deposits and anaerobic conditions when untreated wastewater is discharged to the environment.
Biodegradable organics	Are principally made up of proteins, carbohydrates and fats. They are commonly measured in terms of BOD and COD. If discharged into inland rivers, streams or lakes, their biological stabilisation can deplete natural oxygen resources and cause septic conditions that are detrimental to aquatic species.
Pathogenic organisms	Can cause infectious diseases.
Priority pollutants (including organic and inorganic compounds)	May be highly toxic and/or provoke cancer, cause genetic damage or malformations.
Refractory organics	Tend to resist conventional wastewater treatment including surfactants, phenols and agricultural pesticides.
Heavy metals	Usually added by commercial and industrial activities. Must be removed when wastewater is reused.
Dissolved inorganic constituents	Such as calcium, sodium and sulphate, which are often initially added to domestic water supplies, and may have to be removed for wastewater reuse.

Source: Adapted from Metcalf and Eddy, Inc., *Wastewater Engineering*, 3rd edition; in United Nations (2003).

Hence, the estimation of benefits arising from wastewater treatment is often biased, given that "the existence of a positive willingness to pay for water quality improvement depends upon the ability of people to perceive water quality changes when such changes do in fact occur" (Rodriguez, 2009; see also Poulos *et al.*, 2006). Thirdly, current valuation studies estimate willingness-to-pay (WTP) for a given improvement in water quality. However, it is difficult to estimate a general relationship between a reduction in pollutants and a change in water quality since this highly depends on the receiving aquatic environment (Howarth *et al.*, 2001). It has also to be taken into account that an aggregation of values stemming from WTP studies for water improvement is not possible, as they are depending on the availability of substitutes. The quantified results can therefore not be applied to all water bodies at the same time (Howarth *et al.* 2001).

3.2.1 Health benefits

Treating wastewater before discharging it into the environment delivers health benefits to those connected to receiving waters further downstream. This applies in particular to those which withdraw water for consumption without prior pre-treatment. While benefits from safe access to drinking water have been discussed in Chapter 2, additional health benefits resulting from wastewater treatment are presented here. Box 3.1 illustrates the potential negative impacts of malfunctioning treatment plants.

Box 3.1. **Epidemics in France due to malfunctioning treatment plants**

In the last 30 years, several episodes of epidemics have been linked to problems of sanitation and to poor operation and maintenance of sewage systems (*e.g.* leaks, connection problems or contamination of seafood through effluents insufficiently treated). Between 1974 and 1979, for example, about 15 epidemics were reported in France. As an illustration, strong rains on the 14th, 15th and 16th of November 2002 led to an epidemic of gastroenteritis in four local communities in the Isère Region connected to the same water network. The capacity of the wastewater treatment plant had been exceeded so non-treated effluent was discharged directly into the river, upstream of a drinking water abstraction zone. The drinking water protection zone was flooded and the drinking water network contaminated by parasites coming from the river. As a result, 300 cases of gastroenteritis (or nearly 10% of the total population) had to be treated in the four local communities in the days following the flood event.

Source: Beaudeau 2006, in AESN (2007).

In the OECD report on the "Costs of inaction of selected environmental policy challenges" (OECD, 2008) health benefits of reducing water pollution linked to recreational activities are presented. The results of some of those studies are presented in Table 3.2.

Table 3.2. **Valuation of health benefits of quality improvements of recreational waters**

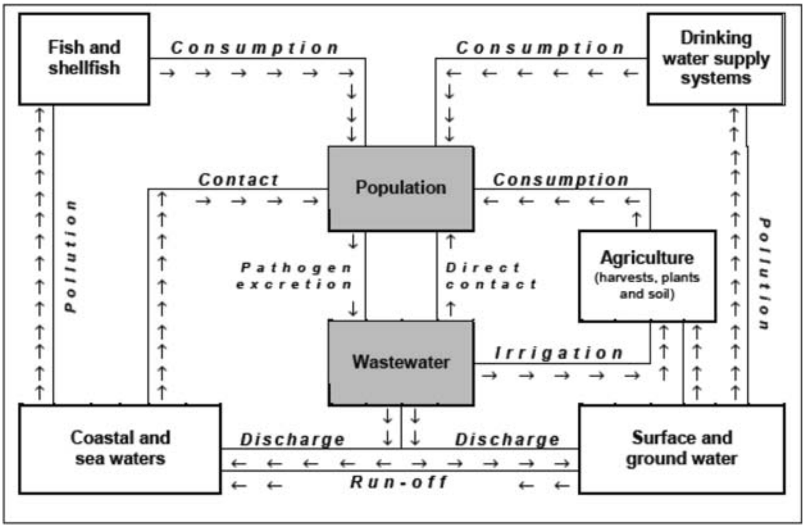
Scenario assessed	Studies	Benefits of Policy Intervention/ Costs of Inaction
Health benefits of quality improvement of recreational waters in south-west Scotland (UK)	Hanley *et al.* (2003)	GBP 1.3 million per year
Health benefits of improving the quality of recreational waters in Brest harbour (France)	Le Goffe (1995)	EUR 33.23 per household per year
Improving the quality of recreational waters in the UK	Georgiou *et al.* (2005)	25% reduction of illness: GBP 11.9 billion/100% reduction: GBP 22.8 billion for a 25-years period
Improving the quality of recreational waters in the Netherlands	Brouwer and Bronda (2005)	EUR 2.4 billion for a 20-year period

Source: OECD (2008): selected examples.

Untreated wastewater can affect human health via different pathways not limited to drinking water consumption. Figure 3.2 illustrates the possible forms of human exposure to pollution caused by wastewater discharges. Jouravlev (2004) summarises health risks of untreated wastewater discharges to the following exposure mechanisms: *(i)* consumption of untreated water; *(ii)* consumption of foods produced with contaminated irrigation water or from livestock farms that use such water; *(iii)* direct physical contact in recreational, bathing or work activities; and *(iv)* the fact that wastewaters are an ideal breeding ground for flies and mosquitoes, which when coming into contact with utensils, food or persons who live or work in areas close to the river, can contaminate them with pathogenic micro-organisms.

Furthermore, adequate management techniques of sewage sludge disposal can provide health benefits linked to reducing the pollutant content in the sludge. This concerns different types of exposures to sewage sludge, including employees in sewage works, recreational users of areas where sewage has been applied or crops grown on land fertilised with sewage sludge (Ayres *et al.*, 2008).

Figure 3.2. **Main forms of human exposure to pollution caused by wastewater discharges**



Source: adapted from Bosch *et al.*, 2000, in: Jouravlev, 2004.

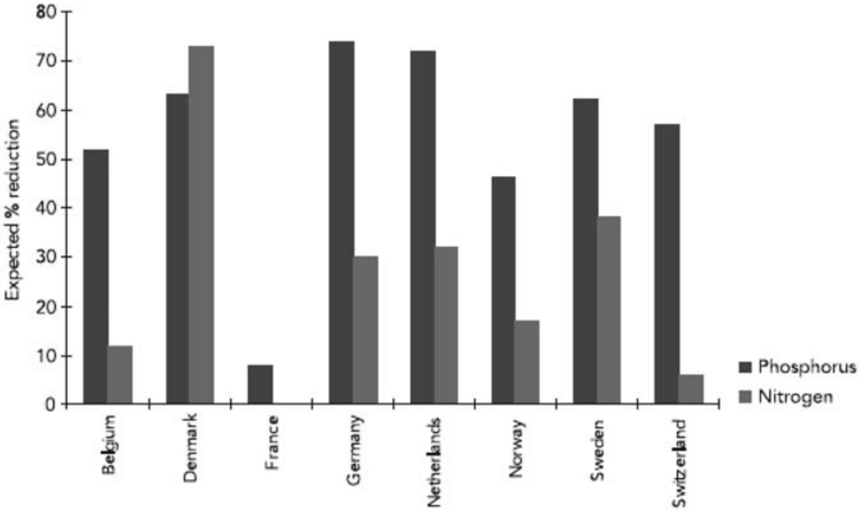
3.2.2 Environmental benefits

In Europe, natural waters were long supposed to be self-purifying, independent of the load of nutrients they receive. As a consequence, very large quantities of nutrients – phosphorous and nitrogen in particular – were released into rivers and lakes through untreated wastewater discharges. This contributed to a significant reduction in nutrient-poor surface water bodies and related flora and fauna (Crouzet *et al.*, 1999).

One important benefit of treating wastewater before discharging it to the environment is that the amount of nutrients is significantly reduced and that eutrophication, with all its negative impacts, can be avoided (AESN, 2007; Howarth *et al.*, 2001). Increased amounts of nutrients released into water bodies can lead to eutrophication. This involves the development of phytoplankton (algal bloom) with a significant impact on the aquatic environment. In particular, related fluctuations in the oxygen concentration can lead to the disappearance of fauna (*e.g.* certain fish species) and flora (AESN, 2007; Howarth *et al.*, 2001). A surplus of nutrients provokes rigorous changes in the aquatic ecosystems and is generally accompanied by a significant reduction in biodiversity (Crouzet *et al.*, 1999).

This requires a given treatment level as pre-condition, however. The first European wastewater treatment plants were concentrating on the removal of organic matter. Additional biological treatment and precipitation mechanisms that effectively remove phosphorous from wastewater were built in Europe only over the last 40 years and treatment plants with corresponding processes for nitrogen removal have been constructed over the last 25 years. Hence, the environmental degradation which took place in Europe up to the 1970s was turned to improvement during the 1980s and 1990s, mainly as a result of improved urban wastewater treatment. Figure 3.3 shows the estimated reduction of nitrogen and phosphorous from municipal treatment plants between 1985 and 1995 in different countries (Crouzet *et al.*, 1999).

Figure 3.3. **Estimated reduction of nitrogen and phosphorous**
from municipal treatment plants between 1985-1995



Source: OSPAR 1995, in Crouzet *et al.*, 1999.

For the environment, not only nutrient reduction, but also the amount of suspended solids discharged into water bodies is important. If they are in large quantities, suspended solids can prevent sunlight reaching underwater plant life. This affects aquatic growth and productivity and can result in food shortages for other living organisms (Wilson, 2000). Furthermore, the aquatic environment can be affected by stream sedimentation[6] or toxic chemicals related to untreated wastewater. This can equally lead to reductions in aquatic species populations or in diversity and negatively influences stewardship, altruistic, bequest and existence values given to the specific ecosystem (Dumas & Schuhmann, 2004).

A positive impact on the ecology of the aquatic environment can therefore be assigned to wastewater treatment.[7] In Paris, for example, additional efforts to increase the wastewater treatment capacity from 1997 to 2000 had clear impacts on water quality. Analyses made since 2000 showed good or very good water quality in 80% of the cases. Furthermore, a considerable improvement of the ecological quality and the fish fauna was recorded (AESN, 2007).

Many studies worldwide have sought to translate environmental benefits into monetary values. Atkins and Burdon (2006) found that people in the Århus County (Denmark) were willing to pay € 12.02 (USD 16.39) per month and per person over a 10 year period for improving the water quality of the Randers Fjord by reducing eutrophication.

General income levels clearly affect willingness-to-pay, however. Ready *et al.* (1998) found in a contingent valuation study widespread support for improvement of river quality through investments in sewage treatment among Latvian residents. The stated willingness-to-pay was limited to 0.13 Lats per month (0.26 USD), representing a 7% percent increase on the current tariff level. Birol *et al.* (2009) investigated the WTP of the population in the Chandemagore Municipality, India, for an improved wastewater treatment of discharges to the river Ganga. Their study revealed an average willingness-to-pay of Rs 16.46 (USD 0.35) per month per household (equivalent to USD 4.25 per year) for additional municipal taxes spent on improving wastewater treatment (volumes treated and treatment level) and reducing environmental and health risks related to polluting discharges to the river Ganga.[8]

3.2.3 Benefits for the economy

Wastewater treatment provides not only health and environmental benefits, but also influences the quality of water resources available for different economic sectors downstream in the same river basin (Jouravlev, 2004). The benefits of wastewater treatment for different economic sectors and activities requiring good water quality are described below.

Benefits for the water supply sector

Wastewater treatment results in lower pre-treatment costs for downstream users. The quality of the water resources determines the possibility to use it for producing drinking water (AESN, 2007). In densely populated river basins, the wastewater discharge point for one urban centre is often located just a few kilometres upstream of the water intake area of another city, so that the time the pollutants remain in the environment before the water is used again is not enough for sufficient natural decomposition and dispersion processes. The content of organic material, chemicals and other pollutants leads to higher pre-treatment costs for drinking water. If no pre-treatment takes place, damages to public health can occur as well as higher costs for supply from more distant sources or from rationing (Jouravlev, 2004). Some additional costs have been quantified for the Sebou basin, in the region of Fès, Morocco (see Box 3.2).

Box 3.2. **Water quality degradation in the Sebou river basin (Morocco)**

Water quality in the Sebou basin (Morocco) has been considerably affected by local industry growth, the development of the agricultural sector, progressive urbanisation and the lack of control over the discharges from these different sectors. A net degradation has been observed on the major part of the watercourse, including at the drinking water abstraction point. Water quality in the Sebou river basin drops in particular during the period in which olive mills are working, as they generate an important pollution charge. In addition to the costs from additional treatment needs, the olive mills also cause a seasonal doubling in energy prices. As a consequence, the institution in charge of the drinking water production in the region (ONEP) has serious problems producing drinking water with a satisfying quality at an acceptable price.

For example, in the city of Fès, water is sold for 1.76 dirham/m^3 (about USD 0.21). According to ONEP, the additional costs for water production reach 6 dirhams/m^3 (USD 0.73), representing 340% of the selling price. Due to the seasonality of the phenomenon (olive mills operate mainly from November to February), the influence of the olive mills resulting from the lack of available treatment for their discharges can easily be identified. However, it has to be kept in mind that domestic pollution is the most important pressure in the basin, with the city of Fès causing 95% of discharges. Challenges in the Sebou basin are therefore manifold.

Source: AESN, 2007.

Eutrophication can also affect the use of water from lakes and reservoirs for the purpose of water production. According to Meybeck *et al.* (1987) and Crouzet *et al.* (1999), the following problems related to eutrophication can influence public water supply and pre-treatment activities: clogging of filters in water pre-treatment plants; undesirable tastes, odours and colour caused by algae; presence of toxins liberated by certain cyanobacteria; etc.

In the Paldang reservoir in Korea for example, which supplies drinking water to 5.8 million households in the Seoul metropolitan area, water quality has become so bad that it was no longer suitable for drinking water purposes due to liquid waste from the manufacturing industry and wastewater from livestock farming. As a solution, stricter regulations for both the agricultural sector and wastewater treatment for factories discharging effluent were applied. As those measures have significant economic costs, Cho and Kim (2004) determined the willingness-to-pay of the population supplied by the Paldang reservoir, which turned out to be an average of about USD 1.30 per household per month for the 5.8 million households concerned. This was deemed sufficient to pay for the full cost of providing improved water quality. Although one of the study's objective was "to help policy makers find the socially optimal level of abatement for water contamination in Korea", it is to be noted that the investment plan had already started when the cost-benefit analysis was carried out, pointing to the fact that the study was partly used as an ex-post justification rather than an ex-ante evaluation of options.

Benefits for industry

Water is used for many industrial purposes, as it can be incorporated into the finished product or used for intermediary purposes such as dilution, cooling or washing. The sectors with the highest water consumption are thermal plants and nuclear power plants (cooling water) as well as papermaking industries (AESN, 2007). Depending on the type of industry (*e.g.* paper and food processing), high-quality water is needed for the production process (Bingham *et al.*, 2000). Accordingly, if water quality is low due to untreated wastewater discharges, water must be treated before it can be used and pretreatment costs lower the net economic benefits associated with using this water (Dumas & Schuhmann, 2004).

However, the benefits of treated wastewater for the industrial sector are not very easy to identify and value, as industries often attempt to take water from less polluted water bodies upstream. If this generates additional costs, benefits from wastewater treatment can be measured in the form of avoided costs. Whenever or not these additional costs can be evaluated will depend on the local situation. Furthermore, industrial reuse of water and internal recycling can reach up to 85% of the total consumption for certain countries and types of industries, limiting therefore the impact of the quality of incoming water (AESN, 2007).

Benefits on fishing and angling activities

Clean water provides life support to fish species. As the success of commercial fishing activities is directly related to the health of the stock of commercially exploitable fish species, poor water quality – *e.g.* leading to reductions in dissolved oxygen – can result in increased fishing costs and prices for fish (Bingham *et al.*, 2000; Dumas & Schuhmann, 2004). Church *et al.* (2008) state in their study on the benefits of improving water quality for recreational activities that very good water quality is essential for fish populations and therefore also for angling and fishing activities.[9] Foster Ingeneria Limitada (2001, in Jouravlev, 2004) indicates that there is an annual loss of about USD 1 million linked to the disappearance of fish from the middle and lower courses of the Bogota river, Colombia, due to increased water pollution (following discharges of untreated wastewater).

In the Black Sea, the degradation of water quality due to an enrichment in nutrients led to an important increase in the algal mass. After a larger imbalance of the ecosystem in the 1970s and 1980s, the mass of dead fish was estimated at around five million tons between 1973 and 1990, corresponding to a loss of approximately USD 2 billion (AESN 2007). Hutton *et al.* (2008), which looked at the impact of poor sanitation in Southeast Asia, also quantified the negative effect of the release of untreated sewage into the aquatic environment on fish production.

Table 3.3 indicates the economic losses linked to the reduction in fish catch in four Southeast Asian countries.

Table 3.3. **Economic losses for fish production due to poor sanitation**

	Total value (million USD)	Per capita (USD)
Cambodia	10.9	0.8
Indonesia	92.0	0.4
Philippines	9.6	0.1
Vietnam	27.4	0.3

Source: Hutton *et al.* (2008).

Note: The figures are based on the value of lost sales.

Benefits for aquaculture

Aquaculture depends on good water quality, independent of the species chosen. Fish or shellfish all depend on water to live, eat and grow. The success of aquaculture relies greatly on its ability to manage water quality (Buttner *et al.*, 1993). For example, oyster production needs to take place in areas where the contamination risk through coliform bacteria is reduced (see Box 3.3).

In the case of the Halifax Harbour, it has been estimated that sewage treatment would lead to economic benefits between USD 230 000/year and USD 380 000/year from reopened shellfisheries (Wilson, 2000).

Box 3.3. **Aquaculture in Morlaix (France)**

To protect its oyster production, the city of Morlaix (France) undertook efforts against the detrimental effects of diffuse and non-controlled emissions from the agglomerations and tourism activities. Until 1992, efforts to reduce diffuse emissions coming from wastewater not discharged into the sewerage network were undertaken. As a result, infectious periods with concentrations above 10 000 coliform bacteria/100g nearly disappeared. A further improvement of the water quality took place in 1996 through the augmentation of the capacity of the wastewater treatment plant. Thereafter, the concentrations of coliform bacteria have been found to be limited to 1 000/100g, which reduces strongly the time needed until the oysters are suitable for human consumption.

Source: AESN, 2007.

Economic impacts on tourism

Water quality is an essential factor for certain tourism activities and sewage treatment leads to enhanced tourist attraction (Wilson, 2000). In several countries, non-compliance with certain norms for bathing water leads to the closure of beaches and lakes for recreational purposes and therefore influences strongly the local tourism economy. This can be avoided through wastewater treatment that reduces bacterial and other contamination (AESN, 2007; Wilson, 2000).

In Normandy (France), it has been estimated that closing 40% of the coastal beaches would lead to a sudden drop of 14% of all visits, corresponding to a loss of EUR 350 million per year and the potential loss of 2 000 local jobs (AESN, 2007). In the Black Sea, it has been reported that a significant surplus of nutrients led to a reduced number of visits by tourists and a shortfall for the tourism industry. It has been estimated that, in 1995, the annual economic loss linked to the disaffection of tourists for this region was about 360 million dollar for each 10% reduction in the quality of the local aquatic environment (Roger Aertgaerts, in AESN, 2007).

Benefits for agriculture

Water which has been polluted by human activities can potentially become inappropriate for animal consumption and/or irrigation. This applies to both water extracted from polluted water bodies and the direct reuse of wastewater. Whereas irrigation with raw wastewater increases the risk factors for the population's health (*e.g.* potentially favouring the spread of diarrhoea, cholera, parasitism and other diseases) (Jouravlev, 2004), treating wastewater enhances the possibilities of using water for agriculture. This applies both to treated wastewater, which can be directly used for irrigation, and to surface water, which is of better quality as a result of sewage treatment. This can lead to increases in area under irrigation, lead to improved crop yields (due to the remaining nutrients) and provide enhanced marketing opportunities (if compared to agricultural products which have been irrigated with untreated wastewater) (Jouravlev, 2004, see also El Madani & Strosser, 2008). The residual sludge can also be used in the agricultural sector, if it is adequately handled (see chapter 5.1). Benefits can be measured in terms of the reduced need to use fertilisers (Andersen, 2001).[10]

In the Mediterranean region, reuse of treated wastewater is done for around 30% of the wastewater discharged.[11] It is mainly applied as irrigation water for agricultural land and green spaces. At a global scale, wastewater reuse offers a promising solution in the short-term, as it allows reacting efficiently to the needs of different water scarce areas (AESN, 2007). For the Sebou basin in Morocco, for example, it has been estimated that the bad water quality of surface water bodies is limiting the irrigated area by about 44 400 ha, which represents a production loss of about 378.6 million DH (USD 47.3 million) (El Madani & Strosser, 2008).

Recycling of some of the nutrients contained in wastewater (such as phosphorus, used in fertilisers) can also play a key role, particularly in the context of declining phosphorus availability across the world (see http://phosphorus.global-connections.nl).

(Indirect) Benefits for energy production

Wastewater treatment processes can also indirectly be used to produce energy. Organic solids which result from the wastewater treatment process produce biogas during anaerobic digestion. This can be used to generate on-site electrical power (see also Section 0 on the use of biogas for household energy production in developing countries). However, the technology is still innovative. Further developments are ongoing to refine the biogas to a quality which for example can be fed into the natural gas grid (Peng and Peng, 2008). In Sweden, a pilot project for producing biogas in wastewater treatment processes for use in vehicles has already started in 1996 (Energie-Cités 1999). A second energy source related to wastewater is its average temperature, which lies around 15°C. Cost-effective heat-exchange technologies allow to extract a part of the heat and to use it as a supplementary heat source in a centralised community heating system.

Benefits for the national economy

Apart from economic benefits which occur either to individual companies or sectors, Jouravlev (2004) states that water pollution linked to untreated wastewater discharges affects also national competitiveness, as the access to external markets is increasingly linked to environmental standards applied in the country of origin of the respective product. Those standards are increasingly causing disputes as non-tariff barriers in international trade. Jouravlev cites the example of Peru, which experienced losses in fish product exports exceeding USD 700 million, due to a cholera epidemic in 1991 (WHO 1999, in Jouravlev, 2004).

Restrictions on its access to external markets was one factor which led Chile to initiate an ambitious investment programme for wastewater treatment, as irrigation with untreated wastewater was estimated to hinder exports of Chilean agricultural products. The required investments of about USD 2 billion were financed through a combination of public and private funds, as the water companies were privatised via a sale of assets. By 2004, all water and sewerage companies in the country had been privatised and the coverage with wastewater treatment grew from 8% in 1989 to 71% in 2003, with the forecast to exceed 98% in 2010. In Santiago de Chile, tariffs increased by 25% due to the investments (different sources, in Jouravlev, 2004).

3.2.4 Other benefits

Wastewater treatment does not only provide benefits for health, the environment and different economic sectors, but also some benefits which are more difficult to capture.

Aquatic environments have an aesthetic value which can be affected by water quantity and quality changes. The enjoyment which humans receive when viewing water resources and the surrounding environment can be compromised through chemicals that harm aquatic organisms but also through eutrophication which changes the whole aquatic ecosystem (Bingham *et al.*, 2000). Aesthetic benefits are therefore directly linked to benefits from recreation activities near water bodies, like hiking, picnicking or photography (Carson & Mitchell, 1993), but also for example bird watching – both due to aesthetic reasons and to the fact that improved water quality might increase bird populations (Church *et al.*, 2008).

Different recreational activities are linked to water and are influenced by water pollution. This includes for example in-stream uses like swimming, boating, fishing (see above), hunting, and plant gathering. Wastewater treatment can for example eliminate infestations by pathogens (*e.g.* toxic cyanobacteria) which could otherwise impede swimming and other forms of recreation with direct water contact (Bingham *et al.*, 2000; Crouzet *et al.*, 1999).

Bingham *et al.* (2000; see also Chapter 3.2 for the total benefits) estimated the value of different recreational benefits across the United States due to an improved control of point-source water pollution, including through wastewater treatment. The study found that the additional benefits due to an improved water quality lay between USD 3.4 million and USD 9.8 million per year for boat cruising, between USD 0.4 million and USD 1.4 million per year for sailing and between USD 9.1 million and USD 46.5 million per year for wildlife viewing.

However, not all water pollutants affect participation in water-related recreation to the same extent. Mainly water clarity is used as a criterion for recreational users, but also odour or algal masses (Church *et al.*, 2008; Crouzet *et al.*, 1999). All factors are clearly influenced by wastewater treatment that reduces sediment loads to the aquatic ecosystems and reduces eutrophication risk.

Benefits for property owners. People living in the surroundings of water bodies benefit from increased stream-side property values as wastewater treatment ensures a certain quality of the water bodies (Dumas & Schuhmann, 2004). It also reduces bad smells and improves the quality of groundwater (Jouravlev, 2004). Wilson (2000) cites several studies which demonstrated that housing prices rise with better water quality. In the proximity of the area which benefited from improved water quality, property values were found to be between 11% and 18% higher as compared to properties next to water of low quality.

Specific benefits of constructed wetlands. Next to the benefits linked to its wastewater treatment function, some specific benefits are attributable to constructed wetlands. These particularly include habitat provision and related biodiversity. Kazmierczak (2001) looked at the economic value of water quality services provided by 12 different wetlands. The values he found ranged between USD 2.85/acre/year and USD 5 673.80/acre/year (with a mean and median of USD 825.04/acre/year and USD 210.93/acre/year, respectively).[12] The geographic location and the specific demand of users for water quality are the most important factors explaining the high differences in value. In general, it has to be kept in mind that values regarding the treatment function can only be attributed to wetlands if they are built near urban areas or industrial discharge areas.

3.2.5 Aggregated benefit values

Studies providing aggregated values for the benefits of wastewater treatment are rare. One example of such aggregated study looked at the quantified negative impacts of untreated wastewater discharges into the Bogota River, Colombia (see Table 3.4). The total annual value of costs linked to the lack of wastewater treatment was estimated at about USD 110 million, including considerable economic damages in different sectors.

Table 3.4. **Economic impacts of pollution of the Bogota River caused by untreated wastewater discharges**

Type of impact	Size of impact	Percentage
Impact on land value. This is the increased value of the land linked to a reduction in bad smells, improvement in groundwater quality and other effects connected with water pollution control.	USD 61 million/year	54%
Impacts on agricultural production. The use of contaminated water from the river and its tributaries for irrigation has significant negative impacts on the quality of the food produced. If water of acceptable quality was available, the irrigation coverage could be extended, and the quality of the agricultural products would be improved.	USD 35 million/year	32%
Impacts on municipal public services. Improvement of the river water quality could allow some communities to use the river as a water source for their water supply systems. The benefit would then be equivalent to the reduction in the costs of obtaining water for the water supply system, and the reduction in rationing and treatment costs incurred by communities which have no alternative sources.	USD 9 million/year	8%
Impacts on the health of the population directly exposed. Persons living close to the river and to the lower part of its urban tributaries are exposed to water pollutants through several mechanisms: *(i)* consumption of untreated water; *(ii)* consumption of foods produced with contaminated irrigation water or from livestock farms that use such water; *(iii)* direct physical contact in recreational, bathing or work activities; and *(iv)* flies and mosquitoes breeding in the polluted water and transferring pathogenic micro-organisms to settlements.	USD 4 million/year	4%
Impacts on sedimentation of river and lake beds. The discharge of residual waters generates sedimentation, owing to the solids present in the waters. This increases the costs of dredging the river and the Muña reservoir and also impedes the natural drainage of waters to the river, whenever the level of the bed has been raised by this gradual sedimentation. The latter created also the need to construct dikes along the length of the river.	USD 1 million/year	1%
Impacts on fishing. In the past, the course of the river Bogotá and its tributaries were rich in fish. With the increasing pollution, the fish have disappeared from the middle and lower courses of the river, and are now found only in the high and turbulent sectors, which are pollution-free, and in some reservoirs and lagoons.	just under USD 1 million/ year	1%
Total	**~ USD 111 million/year**	**100%**

Source: Adapted from Foster Ingenieria Limitada (2001), in Jouravlev (2004).

Note: The total value does not include all of the damages caused by pollution: *(i)* health impacts on the population indirectly exposed; *(ii)* impacts on the operation and maintenance costs of the hydroelectric plants of the river; *(iii)* impacts on the benthic and avifauna biodiversity; and (iv) impacts on the landscape and odours in the vicinity of the river.

Notes

1. This section is focused on wastewater treatment, as methods for collecting and storing human excreta through on-site sanitation solutions are dealt with in Section 2 focused on providing access to sanitation services.
2. David Lloyd-Owen, presentation at the OECD Expert Meeting on Water Economics and Financing, 15 March 2010, Paris.
3. WaterAid (forthcoming).
4. David Lloyd-Owen, *ibid.*
5. Non-use benefits accrue to individuals regardless of whether or not they have direct interaction with water.
6. Wastewater treatment and its reduction of sedimentation reduces also the costs of dredging rivers and reservoirs and assures natural drainage (which is impeded if the river bed becomes too high due to sedimentation (Jouravlev 2004).
7. In general, it has to be taken into account that less than half of the nitrogen loads to surface waters are stemming from wastewater. However, sewage effluents contain nitrogen also in its ammonium form, which is especially harmful to the aquatic environment (Crouzet *et al.* 1999).
8. However, the aggregated amount is not enough to allow for investments to treat 100% of the wastewater generated by the municipality. Budget constraints mean that it is necessary to search for additional financing sources (Birol *et al.* 2009).
9. Hutton *et al.* (2008) also mentions that the high nutrient content of wastewater can also be good for fish and crop production. This requires careful dosing, however and limiting other harmful pollutants, including pathogens.
10. Untreated wastewater has a certain value due to its nutrient content and the reduction of fertiliser needs. However, the supply of nutrients needs to be limited and the content of other harmful pollutants, including pathogens, heavy metals etc., may limit this direct use of wastewater (Silva-Ochoa and Scott, *after* 2001).
11. This is also the case with very arid countries, such as Qatar (AESN, 2007).
12. All values are in 2000 dollars.

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