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Water Crisis

Water is essential for life; our food cannot grow without water and millions of plants and animals live in it. Despite this, it is taken for granted in many parts of the world. At times it may feel as though there is an infinite stock of freshwater but available freshwater in the world is less than 1% of all the water on earth. The human population has increased enormously and data show that freshwater species are threatened by human activities. The average population of freshwater species fell by around 47% between 1970 and 2000 (UNESCO, 2006). The problems we face today are numerous but we experience only some of them directly. For example, while many people and animals have died due to water scarcity in various parts of the world, excess nitrate runoff is responsible for dead zones (low-oxygen areas in the oceans) in other parts of the world.

Drinking water that is clean and safe is one of the basic needs for the survival of human beings and other species. It has a large effect on our daily lives and therefore civilizations are concentrated around water bodies (Figure 1.1). We may have to pay a certain amount of money to water suppliers to access drinking water, or we may receive the water supply as an amenity from governments.

Although our planet has a large amount of water, estimated at 1.4 billion km^3, only 2.8% consists of freshwater. Moreover, most of this freshwater is contained in polar glaciers, which dramatically reduces the amount of water available to human beings. Renewable water resources decreased from 17 000 m^3 per inhabitant per year in 1950, to 7500 m^3 in 1995 (UNESCO, 1996), and they are continuing to decrease. Water resource distribution is not uniform on the planet and some countries suffer from natural disasters, such as floods or earthquakes. In such cases, the shortage of drinking water becomes a major problem. Water quality can be dramatically reduced, as was the case after the tsunami in Indonesia in 2004 (Barbot *et al.*, 2009).

Statistically there are many problems associated with a lack of a clean freshwater supply. Diseases and contamination are spread through unsafe water and many people become sick as a result. Problems with water are expected to grow worse in the coming decades, with water scarcity occurring globally. In regions currently considered water rich, primary

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Figure 1.1 *Civilization has been mainly concentrated adjacent to water bodies.*

water treatment may not be accessible when natural disasters occur (Shannon *et al.*, 2008). Problems with drinking water in the event of natural disasters often concern microbial pollutants, although organic and inorganic chemical pollutants can also play a role (Ashbolt, 2004). Access, to potable clean and safe drinking water has been reported as a major problem faced by the people affected by natural disasters.

Virtually all business decisions will affect natural resources. Of these natural resources, water is the most affected by business decisions all over the world. As other resources have been extracted, the water fit for direct human consumption diminished; often it is not even directly suitable for other purposes, for example industrial and agricultural uses.

Water stress can be defined as a situation where there is insufficient water for all uses. It results from an increase in population, invention of new uses for water and the use of water bodies as disposal points for wastes. Technology has also made it easy to extract water from the groundwater table, divert surface water flows and transport the water to water-scarce locations. Intense urbanization and industrialization have resulted in climate change, thereby enhancing water scarcity and reducing the sustainable supply. Changing climate has increased water shortages due to variation in precipitation patterns and intensity. The subtropics and mid-latitudes, where most of the world's poorest people live, are likely to become substantially drier (Chandrappa *et al.*, 2011). An increase in the temperature has been linked to glacier/snow-cap melting. This water will ultimately reach the sea, so that it will no longer be useful unless it is treated in costly desalination plants. Extreme weather patterns may result in disasters, affecting the quality of water.

Groundwater-dependent areas (where open wells were once sunk) have now adopted drilling technology to extract ground water through bore wells. This technology was attractive as it reduced the time for sinking a well from 3 months to a day. Failure at one spot does not discourage people from sinking another bore well a few metres away at a greater

depth than the earlier one. Competition amongst neighbours resulted in emptying ground water, within a decade, which had accumulated over thousands of years.

As the perception of water as an infinite resource is diminishing, many attempts have been made around the world to adapt to the situation using wisdom within the community. Some ideas were successful over time; others failed. While the people in Greenland used melted snow to meet their water needs, the people in the Sahara settled around oases. While people in dry areas of India took a bath once a week or once a month, others in the same country tried to build huge dams across rivers and diverted the water course through a system of canals. While the urban agglomeration grew, these approaches could not be sustained. The wisdom of engineers four decades back is no longer meeting the needs of present population. Systems designed half a century ago have placed environmental and economic burdens on countries and communities alike.

Many of the solutions have now become problems. Examples include huge wastewater treatment plants that are not adequate to cater for today's sewage generation. The entrepreneurs who built industries in the past did not bother to construct sound waste-treatment plants. As a result, mankind depends on technology that requires large amounts of energy and chemicals, resulting in high carbon emissions and large ecological footprints.

Negligence and lack of consideration by government (legislative, executive and judiciary) as well as inadequate investment in public drinking water supplies led to adaptive measures like selling water in sachets in some parts of the world. While pollution has encouraged the bottled water industry, water scarcity has adversely affected food security. Irrigation has helped to improve agricultural yields in semi-arid and arid environments (Hanjra *et al.*, 2009a, 2009b) but 40% of the world's food is produced by 19% of the irrigated agricultural land (Molden *et al.*, 2010). Continued demand for water for urban and industrial use has put irrigation water under greater stress.

Figure 1.2 shows the availability of water per person in different regional of the world based on the information available in Ramirez *et al.* (2011). These figures lead to the conclusion that fresh rain water is more available for a person in America than for one in Asia. This is true because Asia has historically more populous countries. Asia also experiences a lower amount of rain due to its geographical location. Some of the largest deserts are in this continent.

Not all of the 112 100 km^3 of water on the surface of the earth is available to humans. It flows and reaches the sea, making less than 3% of the world's water fresh, of which 2.5% is frozen, locked up in the Arctic, on Antarctica as well as in glaciers. Thus, humanity and terrestrial ecosystems have to rely on the 0.5% of global water. But global freshwater distribution is not equal. The following countries possess nearly 60% of the world's freshwater resources: Brazil, Russia, China, Canada, Indonesia, the United States, India, Columbia and the Democratic Republic of Congo. But, it does not mean that all the people in these countries have sufficient water to fulfil their needs. Local variations within these countries are highly significant.

Given that 120 l/person/day is just sufficient to fulfil the water needs of one person, precipitation across the globe is sufficient to meet requirements. Unfortunately, not all the water is shared equally amongst the people across the globe. As shown in Figure 1.3, only 8% of the water used in the world (not water received by the world through precipitation) is supplied to the public by governments across the globe (www.climate.org/topics/water.html, accessed 13 December 2013) and not all people are fortunate enough to have water supplied to their

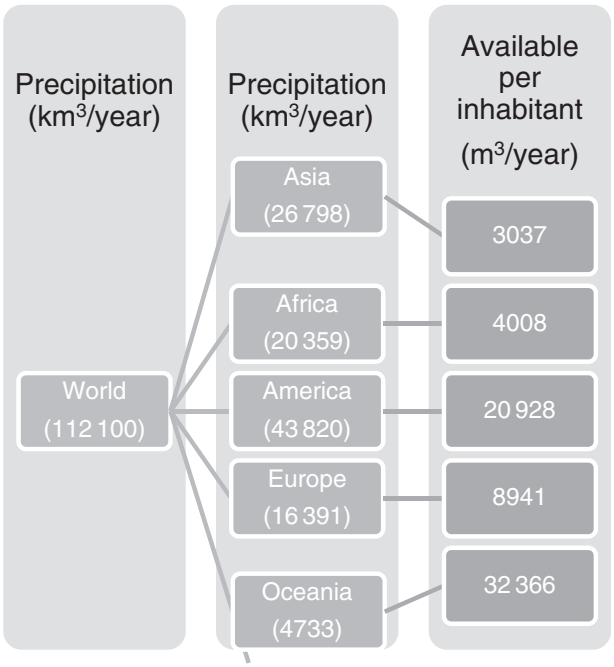

Figure 1.2 *Availability of water per person in different regional of the world (based on the information available in Ramirez* et al.*, 2011).*

home. Apart from human domestic consumption (drinking, cooking, bathing/sanitation and washing) there has been shift in water consumption by industry since the Industrial Revolution. Industrial activity currently consumes 25% of water and agriculture consumes around 67%, leaving behind the rest of the water for other purposes.

Apart from the discrepancies in water availability, discrepancies in purchasing power due to differential financial distribution have created artificial water scarcity. Some of the pets in rich people's houses will have easier access to water than poor and marginal people (Figure 1.4). While the rich and elites enjoy the water (swimming, car washing, long showers in bath tubs, etc.), poor and marginal people may have to satisfy their needs with less than 10 l/person/day.

The Industrial Revolution and associated poor practices and waste management have resulted in pollution and resource degradation. The cost-cutting principles of industrialists lead to poor treatment of wastewater generated. Many entrepreneurs discovered that

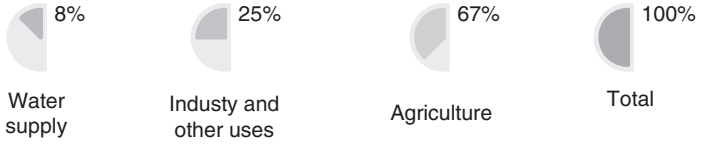

Figure 1.3 *Global water use pattern.*

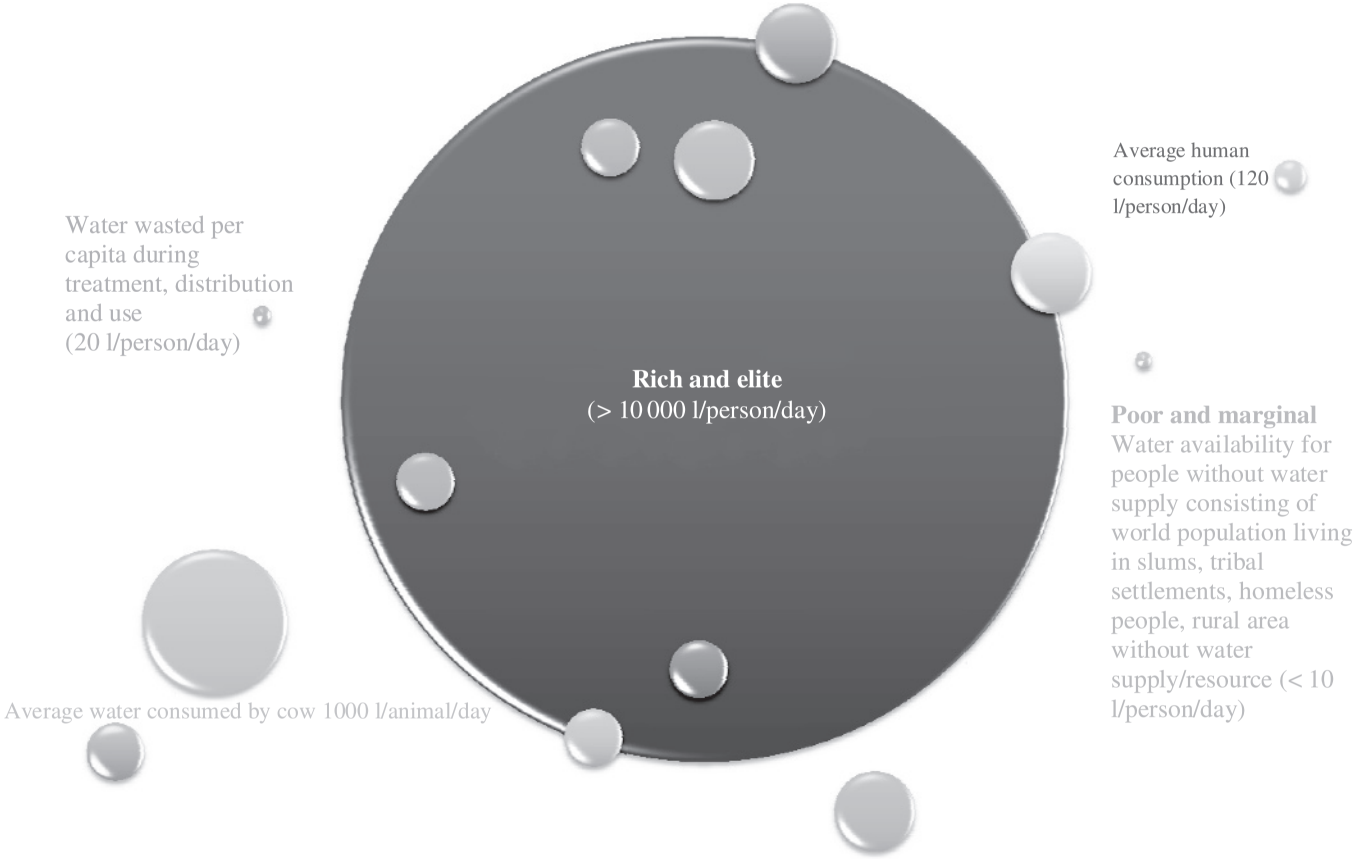

Figure 1.4 *Discrepancies in water consumption between rich, poor and animals.*

'corruption is cheaper than correction' and discharged wastewater without treatment all over the world. But the enactment and enforcement of stringent laws in developed countries make it possible to regain the quality to greater extent. As a result, some of the developed countries lost manufacturing business to other countries like China and India. The textile mills that were landmarks of Manchester in the United Kingdom and Norrkoping in Sweden are no longer manufacturing textiles but India and China, which export garments to Europe and the United States, have added pollution to water bodies.

Agriculture requires more than 60% of global water use and 90% of the use in the developing countries. Global freshwater consumption has more than doubled after World War II and is likely to rise another 25% by 2030.

Asia has 32% of global total freshwater resources but Asia is home to about 60% of the global population. It is projected that 2.4 billion people in Asia will suffer from water stress by 2025 (IGES, 2005). Developing countries have invested in water infrastructure but not in sustainable infrastructure.

Economic development has made countries thirsty. The situations in Europe during the Industrial Revolution made the countries thirsty during the late eighteenth century. China, with an economic growth rate of 10% per annum since the late 1970s, currently has 20% of the global population and has only 7% of the global freshwater to quench its thirst.

On average, the people of southern China have four times more water than the people in the north whereas people in northern India have more water than their counterparts in the south, the reason being that the Himalayan mountain range, with glaciers that feed perennial rivers, is located towards the north in the case of India and the south in the case of China.

Population projections by the UN in 1996 revealed that world population growth is slowing more than previously thought. The UN projections prove that even slight variations in population growth rates can have affect the quantity and quality of water available to each person. Slower population growth has resulted from the desire of millions of people to have fewer children, which is a welcome development for the future.

1.1 Water Resource Issues

Water is used much faster than nature can replace it. Water is a finite resource circulating between the atmosphere and the earth. Long-term water security cannot be guaranteed if rainwater accumulated in aquifers is mined and overused.

Water stress is caused by (i) excessive withdrawal from surface water and groundwater; (ii) water pollution and (iii) inefficient use of water.

Despite water stress, people stay and face water crises for many reasons, some of which are:

1. Inheritance of property/business in the locality.
2. Absence or lack of skills to move to new place.
3. Lack of confidence to live in new place.
4. Resistance from other region or countries to accepting people from some other countries/religion/region.
5. Cultural, linguistic and financial issues.
6. Attachment to land and people.
7. Dependents like children and old people who cannot move to new place independently.

Migration of people to water-abundant areas is not possible in the current context of the political fragmentation of the globe, thereby ruling out this solution. Countries just cannot accept environmental refugees as it will put burden on their citizens and in time may cause poverty among their original citizens.

Sharing water with other countries located far away is not considered for financial reasons. Sharing of water by neighbouring states might be a solution but there are numerous examples where there has been conflict between such states. States/countries/regions release water when there is abundance and hold water when there is water scarcity, thereby causing floods and droughts respectively downstream.

As a result, people are left only with combinations of the following choices:

1. Reduce the population.
2. Reduce consumption of water.
3. Reduce wastage of water.
4. Reduce/avoid water pollution.
5. Reuse/recycle water.

Discussing how to reduce the human population is beyond scope of this book and there have been many attempts across the globe using legislation, increasing awareness and providing incentives in this regard. A reduction in consumption could be done by avoiding water-intensive crops but, people just refuse to switch over from foods with a higher water footprint to those with a lower water footprint. People do not switch over to vegetarian food instead of meat and dairy products to save water, even though the water footprint of vegetarian food is far smaller than that of food derived from animals. Hence, the only choices people prefer to make is (i) reducing wastage, (ii) reducing/avoiding pollution and (iii) reusing/recycling water. This book elaborates on various methodologies, strategies, issues and challenges in achieving these three objectives.

Manmade and natural disasters are often followed by considerable loss of life and temporary disruption of normal life, which may result in suffering and substantial damage to infrastructure, society and the economy. It has been reported that more than 90% of all disasters occur naturally and 95% of disaster-related casualties occur in developing countries (Thuy, 2010). It has also been reported that Asia and the Pacific are the regions that are particularly affected by disasters (Thuy, 2010).

The earthquake in the Republic of China in 1976 was ranked as one of the most devastating events in terms of the number of people killed and economic damage. Asia, with its geographic position and topographic conditions, has special climatic characteristics, resulting in serious disasters such as floods, typhoons, tornados, tsunamis, earthquakes and droughts.

Meanwhile manmade disasters such as war and political violence, apart from death and destruction, also cause disruption to economic networks and contribute to environmental degradation, which in turn jeopardizes food production, water quality and living conditions (Thuy, 2010). It was reported that, in 2008, about 5600 people lost their lives because of human-made disasters such as shipping disasters, mining accidents, stampedes and terrorism (Thuy, 2010).

As well as food, shelter and medical aid, providing clean water is usually one of the highest priorities in the event of an emergency (Reed, 1995). During emergency situations, the shortage of drinking water is not only an inconvenience but its availability and use

under such conditions is also associated with risks that threaten human lives (Thuy, 2010). Effective primary water treatment may not be available to a huge percentage of undeveloped countries. It is therefore essential to have a fully functional portable water purification device in order to live when natural disaster happens. Failure to provide safe water can often be fatal in the wake of natural disasters.

The most popular water treatment methods nowadays include filtration such as sand filtration (Thuy, 2010), bio-sand filtration (Elliott *et al.*, 2008) or membrane filtration (Butler, 2009; McBean, 2009; Park *et al.*, 2009), and coagulation (Garsadi *et al.*, 2008). Normally, these processes do not ensure the disinfection of treated water so a chlorination process is necessary. However, due to the adverse effects from disasters, there is limited access to chemicals such as chlorine or iodine for disinfection and aluminium sulfate for coagulation and also electricity to supply power in order to operate systems. This is the main reason why chemical and electricity requirements are the most important factors that restrict the use of these methods in emergencies (Thuy, 2010).

Membrane technology has emerged and has proven to be an advanced technology for water treatment to produce safe drinking water. Its application is increasing day by day. As compared with conventional treatment methods, water treatment using membrane technology produces a better water quality, uses a much more compact system, is easier to control in terms of operation and maintenance, requires fewer chemicals and produces less sludge (Nakatsuka and Nakate, 1996). The methods to create the driving force for this filtration are more flexible and less dependent on electrical energy; they include use of gravitational force (Butler, 2009), bicycle-powered filtration (McBean, 2009) or wind-powered renewable energy (Park *et al.*, 2009). Research will focus on developing a membrane-based portable water purification system that could be deployed to countries in the wake of natural disasters or for emergencies.

1.1.1 Water Footprint

The water footprint is an indicator of water use with respect to consumer goods (Hoekstra *et al.*, 2011). The water footprint of a product/service is the quantity of freshwater used/evaporated/polluted to produce the product/service. A water footprint has three components: blue, green, and grey (Figure 1.5). The quantity of freshwater evaporated from the surface/groundwater is considered to be the blue footprint. The green water footprint is the quantity of water evaporated from rainwater stored in the soil. The grey water footprint is the quantity of water required so that the quality of the ambient water will be above

Figure 1.5 *Definition of blue, green and grey water footprint. (For a colour version of this figure, see the colour plate section.)*

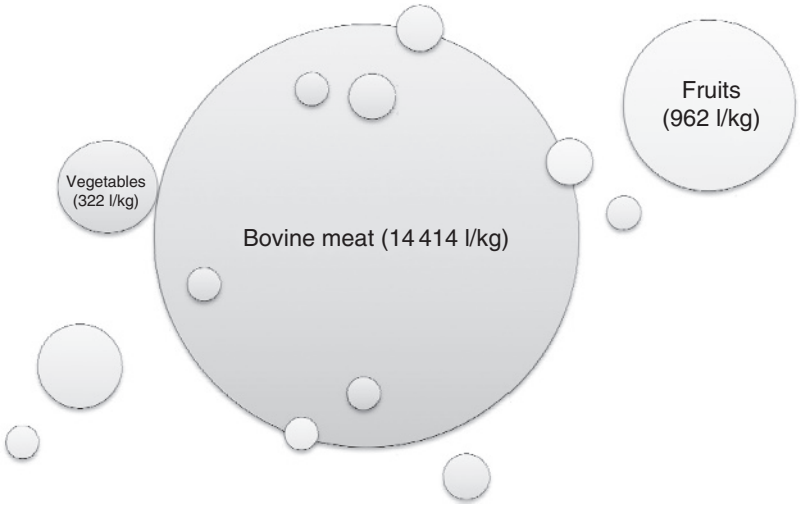

Figure 1.6 *Average footprint for production of vegetables, bovine meat and fruits. (Source: based on data in Mekonnen and Hoekstra, 2010.)*

water quality standards (Hoekstra and Chapagain, 2008). Figure 1.6 shows the average footprint for the production of vegetables, bovine meat and fruits. Twenty-seven per cent of the global water footprint is due to the production of animal products (Mekonnen and Hoekstra, 2010).

Apart from water consumption for food and drinking, the world has witnessed an increase in the use of goods and services, which has left a greater footprint than food production. Hydropower, which accounts for nearly 16% of the global electricity supply, has a blue water footprint of around 90 Gm^3/year which is equivalent to 10% of the blue water footprint of worldwide crop production in the year 2000 (Mekonnen and Hoekstra, 2012). The increase in the number of cars in the world has also placed a high demand on petroleum-based fuel, which is a nonrenewable resource. Hence, the blending of ethanol has been considered as a sustainable solution in many parts of the world and many governments are encouraging production of sugar beet and sugar cane to enhance production of ethanol. The demand for and subsequent diversion of water to grow raw material for ethanol has also resulted in competition for water with conventional uses.

1.2 Climate Change and Its Influence on Global Water Resources

During the Palaeolithic period (before 10 000 BCE) people lived as nomads and there were no permanent settlements and hence no stress on water resources. Humans developed the first stone tools but did not put any stress on water bodies. This was followed by the Neolithic period (or New Stone Age), which started in about 9500 BCE in the Middle East. The Neolithic period was followed by the terminal Holocene Epipalaeolithic period, when farming was started. The Mesolithic period, which occurred 10 000–5000 years ago, saw a growth in population, which started using water resources as well as other natural resources.

Figure 1.7 *Raw material storage in cement plant.*

The era was characterized by widely dispersed, small, semi-permanent settlements and nomads. The Bronze and Iron Ages occurred 5000 years ago, resulting in villages resulting in early forms of human settlement that covered a few acres and supported a population of several thousand. These villages further developed into permanent settlement in dense aggregations.

The Industrial Revolution, from the 1760s to the mid-1800s in Western Europe and North America, witnessed improvements in industrial machinery, iron smelting, cement manufacture (Figure 1.7), thermal power generation, as well as specialization and division of labour. The era witnessed a decline in mortality, an increase in population and an increase in carbon emissions resulting in global warming due to the greenhouse effect leading to change in active layers, the ice cap, ice flow, ice sheets and ice shelves.

A few centuries ago the rivers of the world had sufficient water to meet the needs of humans and animals. Groundwater was manually extracted from wells and crops were usually grown with rainwater. Even today, rainwater-fed agriculture is practised across the globe (Figure 1.8) both for the market and for home consumption. Water pollution was

Figure 1.8 *Preparation of land for rain-fed agriculture.*

Figure 1.9 *Freshwater sources, once abundant, are declining due to climate change, destruction of watersheds and distortion of natural streams.*

caused mainly due to small quantity of human sewage. The world's population was less than 25% of today's level.

Global warming has changed the global water cycle due to rising temperatures and hydrological processes. Changing climatic patterns are causing extended periods of drought or flood, a change in rain patterns, an increase in summer, an increase in average temperature, changes in seasons, changes in flowering patterns in plants, an increase in the sea level and melting of ice in glaciers in mountainous and polar regions. Climate change may increase freshwater availability in some places but it causes stress in most places. Freshwater sources that were once abundant are declining due to climate change, destruction of watersheds and distortion of natural streams (Figure 1.9). The decline in the annual snow-cover extent (SCE) has been about 10% in the Northern Hemisphere since 1966 (Robinson, 1997). Global land precipitation has increased by nearly 2% since the beginning of the twentieth century (Jones and Hulme, 1996; Hulme *et al.*, 1998) but the rise is neither spatially nor temporally uniform (Karl and Knight, 1998; Doherty *et al.*, 1999).

In the mid-twentieth century nearly half a million hectares of land irrigated in Pakistan was going out of production every year due to a buildup of salt as well as an increasingly saline groundwater table (Postel, 1999). Another nearly five million hectares of agricultural land was vulnerable with reduced productivity because of high salt concentrations (UNEP, 2007).

About 3 billion humans will join the current of 6.5 billion in the next 100 years, increasing the scarcity created by climate change. Groundwater reserves that were sufficient to meet needs have already exhausted or are on the verge of exhaustion. Continuation of current trends in global greenhouse gas (GHG) emissions will lead to at least a 25% greater water shortage in the next century (Ackerman and Stanton, 2011).

Climate change in sub-Saharan Africa will have consequences that go beyond agriculture. Studies with respect to Northern Kodofan in Sudan explain that temperatures will increase by 1.5 °C between 2030 and 2060, with rainfall declining by 5% (UNDP, 2007).

1.3 Protection and Enhancement of Natural Watershed and Aquifer Environments

Despite abundant rainfall, Africa is facing water scarcity and 25 African countries are likely to face water scarcity by the year 2025 due to increasing demand for water as a result of population growth, economic development, watershed degradation, pollution and inefficient water use (UNECA, 2008). As shown in Figure 1.10 many watersheds now have urban settlement and waste dumping yards, reducing infiltration and enhancing evaporation as well as pollution. The momentum of urbanization throughout the world due to migration was fuelled by failure of agriculture and loss in crops in rural areas. Migration has led to destruction of watersheds and natural drains. In a hurry to accommodate the incoming population, urban planners neglected the protection of natural and aquifer environments. In some cases the population just did what it felt like for survival and settled within the water drains by diverting and obstructing the natural water flow.

1.4 Water Engineering for Sustainable Coastal and Offshore Environments

The quality of coastal and offshore environment is degrading rapidly due to excess human activities. Growing coastal populations as well as overuse of resources from oceans are the major source of the problem.

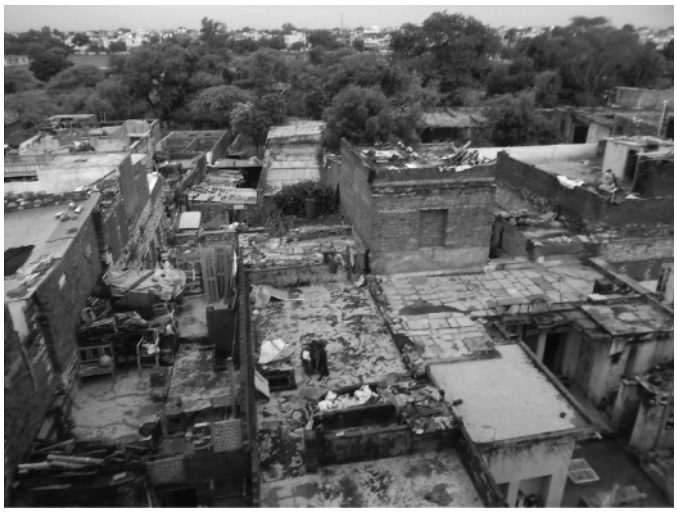

Figure 1.10 *Many watersheds have been converted into urban settlement and waste-dumping yards.*

Figure 1.11 *Activities in coastal areas have been a source of pollution in the fragile ecosystem of estuaries, deltas and the marine environment.*

Activities in coastal area have been a source of pollution in the fragile ecosystems of estuaries, deltas and marine environments (Figure 1.11). Marine pollution is caused by (i) discharge of untreated or poorly treated sewage from human settlements, (ii) pollutants from industries, (iii) runoff from urban area, (iv) solid waste entering due to offshore and onshore activities.

Waste from ships, like oily sludge, food packaging and food waste, finds its way into water despite the discharge of solid waste from ships being forbidden by the International Convention for the Prevention of Pollution from Ships 1973, modified by its Protocol in 1978.

Ports and harbours generate a range of wastes, which include minerals and damaged products (Figure 1.12).

1.5 Endangering World Peace and Security

There are more than 263 international river basins all over the world and more than 145 countries are riparian to these basins (MacQuarrie *et al.*, 2008). Conflicts over water consist of three key spheres: economic, hydrosphere, and political (Cosgrove, 2003). Water scarcity, speeded up by climate change, may threaten peace and security (Tignino, 2010). While some predict wars (Starr, 1991; Bulloch and Darwish, 1993) others point out that no 'water war' has occurred for nearly 45 centuries (Wolf, 1998). Many regions in the Middle East and North Africa are likely to face further decreases in water availability. Reduced agricultural production due to a decline in rainfall is a factor in conflict in Darfur. During the 1950s, the UN Security Council adopted two resolutions concerning development projects in the

Figure 1.12 *Ports and harbours generate a range of wastes, which include minerals and damaged products.*

Jordan River. Water issues were incorporated in the mandate of the Commission in 1980 by the Security Council (Tignino, 2010).

A decline in rainfall and in water resources has increased damage to fragile ecosystems (Figure 1.13) and has caused forest fires. Agriculture has failed (Figure 1.14) in many parts of globe, leading to migration and endangering peace due to changes in demography and the creation of conflicts.

Figure 1.13 *The drop in water resources has increased damage to fragile ecosystem as well as forest fires.*

Figure 1.14 *Failure of agriculture due to drop in water resources.*

1.6 Awareness among Decision Makers and the Public across the World

Awareness among decision makers and the public varies from place to place. Stringent laws in Europe and the United States generally ensure the quality of water supplied meets prescribed standards. In developed countries, cases are disposed of speedily, there are effective redress mechanisms and the public knows its rights. On the other hand slow dispute-resolution and complaint-redress mechanisms in developing countries often discourage the public from approaching the civic authorities and using the judicial system. In such situations, the public often does not bother to know its rights and accept whatever is made available, thinking 'beggars can't be choosers'. Nobody from the public participated in the decision-making process prior to the incorporation of public consultation mechanisms with respect to mega projects around the world. But, since such involvement leads to delay in project and hindrance from people with vested interests, some projects have been exempted from the public consultation process.

Decision makers are sets of people who can withstand the stress, controversy and opposition with respect to decisions taken by them. They are not subject experts and are usually advised by groups of advisors who are, in turn, supplied with data and information about projects or issues by supporting staff. On the other hand the general public will not have advisors and information providers and awareness comes from their educational background, access to information, interest in particular issues, and the time that is available for them to spare dealing with the issues. A poor person who is bothered about wages for survival usually does not bother about arsenic and fluoride content in the groundwater where he works. There have been many instances where people hardly have choice.

The increase in the consumption of packaged water has been attributed to awareness amongst some people. Despite the cost of packaged water being 500 to 1000 times greater than tap water, people choose packaged water in many parts of the world as they have lost faith in quality of tap water.

Since the Stockholm Convention in 1972, many international laws have been passed. In response to international conventions, much environmental legislation has been passed at national level all over the world but the degradation of the environment continues,

throwing the effectiveness of this legislation into doubt. This has attracted environmentalist to produce a variety of recommendations like environmental education at school, awareness and effective communication but the key issue of lack of professionalism in environmental law enforcement and policy-framing organization has stayed in the background. Environmental organization is part of government. The people working in these institutes have either deputed from other government organizations or have recruited in-house people who take motivation from other organizations. The lack of professionalism in government organization ranges from coming into the office late to using office space and time for private purposes. Poor time management coupled with lack of motivation, poor emotional intelligence and lack of respect for the profession add to the inefficiency of the system. It is common to observe many professionals reading newspapers at their desks instead of attending to office work. It is common in some government offices to see people pealing vegetables and tying garlands during office hours for private use. Many government employees use their paid time for worshipping at offices. The late arrival of electricians and hardware/software professionals often hinders the work of others.

Other unprofessional and unethical practices may include use of office staff/vehicles for private purposes. In many cases, the loyalty of government staff/officials to the spouse/children of the head of the office may outweigh their commitment to the responsibilities they are paid for (a practice deriving from monarchy and colonial rule in many developing countries). Official vehicles may be used for personal purposes while personnel struggle to travel for official purposes. Unprofessional record management also often leads to time wasting as the records are searched for quite a long period while decisions are required. Absence of procedural knowledge often results in professionals not attending to the work. Many citizens avoid approaching government offices as the staff in offices beg or demand money even to attend to simple queries. The misplacement of records, corruption, lack of motivation/ethics/ punctuality/loyalty/values and common sense often leads to delay in work, which results in degradation of the environment.

1.7 Criteria for Sustainable Water Management

Sustainable water use and management should provide guidance for the individuals and institutions that use, manage and resolve conflicts. As per, sustainable use of water requires the maintenance of a preferred flow of benefits to a particular place or group, undiminished over time (Gleick, 1998). The World Commission on Environment and Development has indicated that sustainable development is meeting current needs without compromising the position of future generations (World Commission on Environment and Development, 1987).

The standard industrialized world model is not affordable in the developing world. The public drinking water supply is unreliable in Nigeria (Egwari and Aboaba, 2002) and, therefore, drinking water is sold in polythene sachets. In Lagos state, up to 70% of the population is meeting its daily water requirements from sources other than the state municipal supply (Coker, 2004).

Water has historically been managed by governments at local, regional and national level. Decisions are usually taken by a group of people without involving the public (Figure 1.15). Decisions about different development activities occurred discretely without being integrated into water management. As a result, surface and ground water was affected

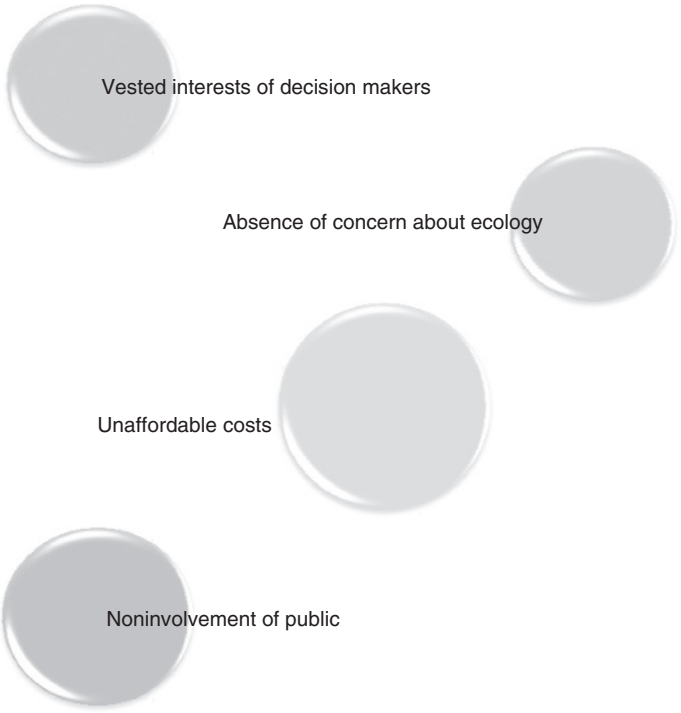

Figure 1.15 *Noninteraction of components in unsustainable water management.*

in various regions. Development activities like the expansion of cities and transportation networks often lead to the fragmentation of watersheds, thereby changing the water flow pattern. Changes in the permeability of soil lead to stagnation and evaporation, resulting in poor ground water recharge capability. The construction of massive dams and water distribution systems without considering their future impact has resulted in disasters as well as ecological imbalance. Such unscientific decisions usually involve corruption and absence of transparency. Where procedures are confidential, without transparency or the involvement of the community, the decisions may be made so as to favour decision makers rather than society or the environment.

Sustainable water management is the current management of water without compromising the needs of future generations. Some of the major recommendations by Postel *et al.* (1996) can be used as criteria for sustainable water management: (i) allocate water to protect the health of ecosystems in the water basin, (ii) eliminate long-term groundwater overdraft, (iii) restructure water institutions to encourage planning for sustainable water use, (iv) link land-use planning and water planning and (v) fill data and information gaps with respect to water. Other criteria for sustainable water management are: (i) maintain a constant water balance within the region, (ii) avoid degradation of the quality of water in the region, (iii) restore water quality within the shortest possible time after disasters, (iv) dissipate information about water quality and quantity continuously to the public, (v) avoid a sudden rise in population density in a few cities due to concentrated development, (vi) predict the impact of all developmental activity on water quality and quantity in the region.

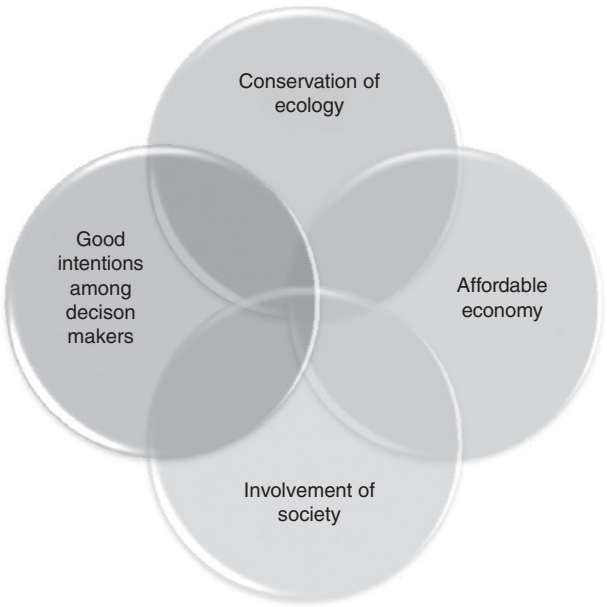

Figure 1.16 *Interaction of components in sustainable water management.*

In a nutshell, unsustainable water management is mainly due to noninteraction of components required for sustainable water management (Figure 1.16): (i) conservation of ecology, (ii) good intentions amongst decision makers, (iii) affordable economy and (iv) the involvement of society.

1.8 Water Scarcity and Millennium Development Goals

The Millennium Development Goals (MDGs) are international development goals that all United Nations member states have agreed to achieve by the year 2015. These goals are:

- eradicating extreme poverty and hunger;
- achieving universal primary education;
- promoting gender equality and empowering women;
- reducing child mortality rates;
- improving maternal health;
- combating HIV/AIDS, malaria and other diseases;
- ensuring environmental sustainability; and
- developing a global partnership for development.

The limits for sustainable water resources have exceeded the threshold of 75% in western Asia as well as northern Africa (UN, 2011). Southern Asia, the Caucasus and Central Asia are approaching the threshold of 60% (UN, 2011).

Domestic budget allocations for drinking water and sanitation have been increasing in some countries but other countries still report insufficient financial resources for them to meet their targets (WHO, 2012). About 1.1 billion urban people and 723 million rural inhabitants have gained access to an improved drinking water source in the period 1990–2008 across the world. Access to water supply and sanitation (WSS) is very low in Africa and nearly half of the population in Africa suffers from one of six major water-related diseases. Improvement in eastern Asia increased from 69% in 1990 to 86% in 2008 and in sub-Saharan Africa access to improved drinking water nearly doubled from 252 million in 1990 to 492 million in 2008 (UN, 2011). Despite increased access to drinking water, the poorest of the poor as well as those disadvantaged because of their sex, ethnicity, age or disability may not receive any benefit.

External assistance in the provision of drinking water and sanitation is provided by multilateral organizations, countries, NGOs and private foundations. Out of the amount invested, some of the infrastructure will be unutilized or underutilized after the project period due to absence of capacity, commitment or funds. Most of the time funding agencies will not look back at funded projects after the project period is over. Even though investments in drinking water and sanitation are increasing, accountability for results achieved remains weak (WHO, 2012).

1.9 Lack of Access to Clean Drinking Water and Sanitation

According to water.org (2009; accessed 13 December 2013), 3.575 million people die every year from water-related disease and 98% of these deaths occur in the developing world. About 1.2 billion people across the world have no access to sanitation at all. These figures clearly indicate issues about historic settlement patterns across the globe. Some countries have made good progress in drinking water coverage. Tanzania and Namibia increased drinking-water coverage from 38% and 58% in 1990 to 73% and 80% respectively in 2002 (WHO and UNICEF, 2004).

Lack of access to clean drinking water could be due to one or many of the following reasons:

1. Financial inability to dig wells or drill bore wells.
2. With the evolution of mankind, nomads started settling where there is an abundance of water but with time people might have moved away from water due to clashes or in search of land. People who inherited land would have lost access to water resources.
3. Rural people who migrated to urban areas in search of jobs ended up in slums and places where water is not available.
4. Earlier generations could have overused water sources beyond their recharge capacity.
5. Water demands due to urbanization and migration might exceed the water available to fulfil the demands.
6. Pollution / contamination due to human/natural causes.
7. Improper use (using ground water in water deficient region to grow crops like sugar cane or rice, which need abundant water).
8. Wastage of water (water loss due to seepage and leakage) and the use of furrow agriculture instead of drip irrigation.

In the past unsustainability of clean drinking water supplies and sanitation occurred mainly due to a poor understanding of the subject and the economics of treatment but the problem has extended into the present despite advances in science and technology. This could be mainly due to professionals in the field making it uneconomical. Hence this book not only looks at various options but also makes an attempt to reduce expenditure by providing orientation to curb expenditure during the establishment and operational stages of water infrastructure.

Water conservation and efficient use and reuse of water have become the need of the day as the planet is facing reduced groundwater and surface-water levels. The water scarcity issue is complicated by drought and changing climate patterns. Water demand management is a useful tool for decreasing luxury water demand, enhancing efficiency and raising awareness about water scarcity. The importance of reducing water demand is highlighted in many parts of the world. One such example is the water-management strategy implemented in Namibia. Due to severe drought, a water-demand-management strategy was implemented in 1994 in Windhoek, Namibia. The key objective was to eliminate luxury water demand and reduce the pressure and the reliance on primary water sources. The strategy was further refined and consists of information campaigns, policy issues, legislation and technical measures.

Another example of water scarcity is that of the Arabian peninsula. Urban water demand has increased rapidly since the 1990s in the Arabian peninsula due to high population growth, better living standards and rapid urbanization. The urban population in the peninsula increased from 6.08 million in 1970 to around 23.12 million in 1995, and is likely to rise from 33.38 million in 2000 to 65 million in 2025. Demand for drinking water is expected to rise from 2269 MCM in 1990 to around 4264 MCM in 2000 and to around 10 580 MCM in 2025 (Abderrahman, 2000). Due to the arid nature of the Arabian Gulf, water is playing a dominant role in human settlements as well as socio-economic interactions (Arab Water Council, 2009). Even though the area was originally dependent upon agriculture, oil and gas have played a major role in the economies of this region since the early twentieth century (Beaumont, 2002). Rapid population growth and urbanization during the first decade of the twenty-first century in the region have created challenges in the provision of infrastructure and public services, including clean water (Kajenthira *et al.*, 2011). Even though agriculture uses the highest percentage of water withdrawal in the Arabian Gulf as well as worldwide, the present economic growth in the region is likely to result in increased quantity of wastewater in the municipal/industrial sectors (Jimenez and Asano, 2008), which should be effectively reclaimed and reused to avoid water scarcity. At present only 65% of the wastewater in the Arabian Peninsula is treated (Kajenthira *et al.*, 2011) and an increase in population and wastewater quantity has resulted in overloaded treatment plants (Qadir *et al.*, 2010).

1.10 Fragmentation of Water Management

Law, responsibility and business bind different authorities and agencies with different territories. The major types of fragmentation in water management include jurisdictional, temporal, territorial, financial, cultural and biophysical (Figure 1.17). Jurisdictional fragmentation occurs when a number of agencies have varied responsibilities over a spatial territory. Jurisdictional fragmentation is created by the political and legal institutions that hold authority in a territory. Water management is shared amongst numerous government actors and can generate a governance gap when jurisdictional responsibility is uncertain.

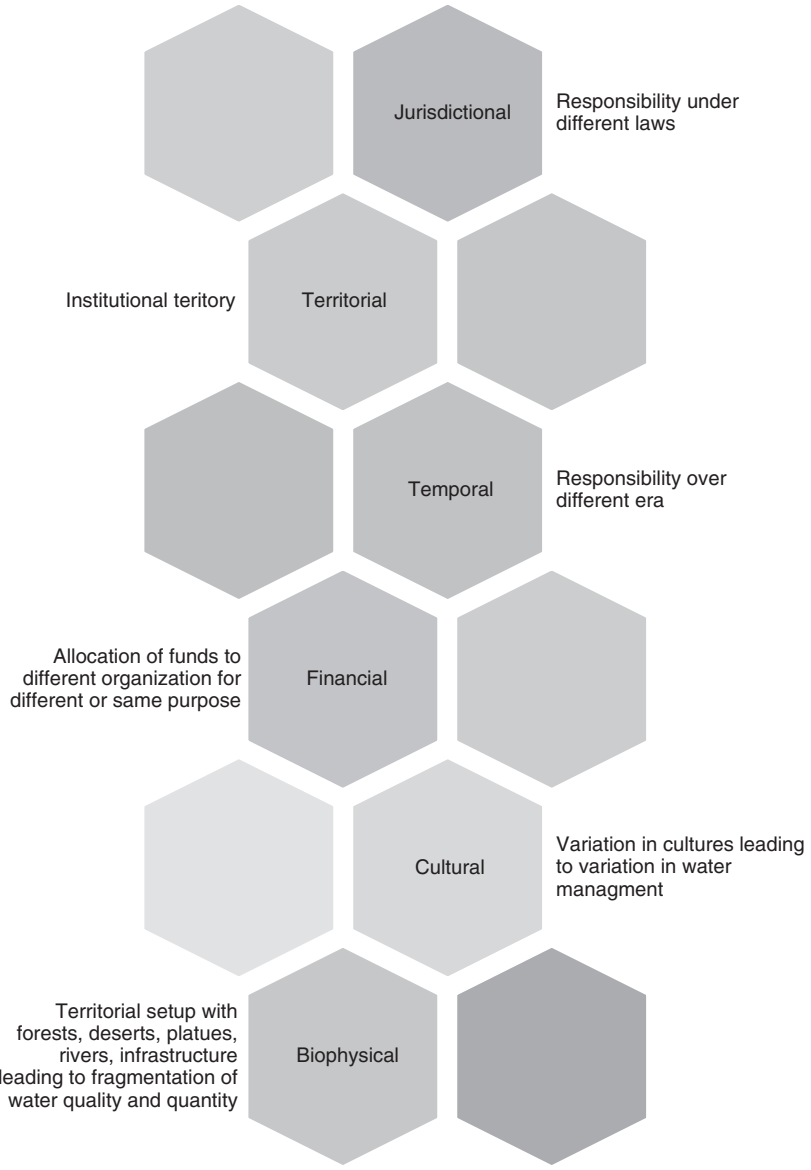

Figure 1.17 *Fragmentation of water management.*

Allocation of responsibility with respect to water governance amongst multiple actors/agencies may lead to relatively little or no coordination.

The agency responsible for water distribution hardly has any jurisdiction to curb pollution by polluters; similarly the agency that is responsible for safeguarding quality does not bother about a reduction in the quantity of water resources. Similarly, the irrigation department usually does not bother about the quality of water or the shortage of water faced by industries.

Temporal fragmentation exists when the effectiveness of one agency is obstructed by the existence of another agency from a different era. The integration of fragmentation is a challenge all over the world.

Biophysical fragmentation of water resources in natural systems can result in fragmentation between land and water; surface water and groundwater; water quantity and water quality; upstream and downstream; or marine and freshwater systems.

Financial fragmentation compels the government to distribute funds amongst different agencies thereby creating an overlap or gaps in responsible spending. The funds released in some places for water and wastewater treatment plants will therefore only ensure the construction of these units without any connectivity to end users. It is also quite common to see urban bodies with sewers and without sewage treatment plants (STPs). There are numerous examples where water-intense industries and projects are cleared by government agencies without looking into their impact on water resources.

Another example of fragmentation is wildlife conservation. The department responsible for conservation of wildlife will hardly have any legal support to initiate legal action on those who deplete water resource or affect quality of water on which wildlife depends.

1.11 Economics and Financial Aspects

The quality of water used in various industrial processes is critical and therefore polluted water resources require additional investment and operational costs. Reduced water availability is affecting food prices. More than one-third of the global population lives in water-stressed nations and by 2025 the number is likely to rise to two-thirds (FAO, 2007). When alternative sources or treatment options are not feasible, industry will be disrupted.

Water and sanitation tussle to receive funds in the developing countries. Developing countries spend between 1% and 3% of their budgets on water and sanitation.

The main risks associated with the water sector are (i) low rate of return, (ii) foreign exchange risk, (iii) risk of political pressure and (iv) contractual risk. Water projects have the additional disadvantage that there is a high minimum size of project finance. Many water projects are not feasible for project finance as they are below the minimum size for financing.

Major funding for the water and wastewater sectors comes from governments, NGOs, banks and private investors, aid agencies, multilateral financial institutions and international organizations. Finance for the water sector comes from (i) state and federal grants, (ii) international donor agencies, (iii) lending from financial institutions and (iv) infrastructure bonds.

The water sector attracted private participation in 68 developing countries between 1990–2005, with most of the investment concentrated in China (56%) and Algeria (34%) (GTZ, 2006).

Some financial approaches for water problems are given in Box 1.1 and case studies of sustainable water financing are given in Box 1.2. The water-financing systems should be coherent, sustainable and adequate. The ideal commercial water finance is low-interest, long-term loans available for subsovereign borrowers. Such loans will usually not have any surety as in the case of private loans.

Box 1.1 Some financial approaches for water problems

Loans with subsidies: Practised in many parts of world, especially with respect to bore wells drilled by farmers. Farmers will pay only part of the amount they borrowed while the rest is paid by government.

Loans without subsidy: Loans borrowed for residences, industries and commercial activity will use part of the expenditure from the loan for drilling bore wells or water connections. Loans from international donors are common practice at a national level.

Loan waive off: Practised in many parts of world by government especially to lure 'vote banks' by waiving off loans for the farming community at the taxpayers' expense.

Equities: Mobilization of funds by the public equity participation of water companies has been the approach in many countries. An investor shares the risk and the profit of a company or project by the purchase of equity shares.

Micro credit: A type of loan extended to poor communities. This approach is commonly used for sanitation.

Micro savings: Saving small amounts for use at a later date.

Lifeline approach: A state/government/donor will provide water free of cost. Donors can be anthropogenic agencies, industries (under corporate social responsibility), temples and so on.

Reimbursement: Reimbursement can be for the urban poor (as in case of Santiago de Chile where municipality reimburses 20% of the poorest urban population) or for those who can afford to pay (as in military settlements and some select government officials as well as people's representatives).

Bonds: A public corporation or municipality may issue bonds that are purchased by private financial institutions. Similarly, private company bonds may be purchased by the public. Usually income-tax benefits would be given to such investments (that is, instead of paying tax the amount can be invested in bonds or the taxpayer will be given a tax rebate).

Infrastructure cess: Cess is nothing but a subtax for a specific purpose. It is usually paid by those who have an income and can afford to pay. In such a scenario a small additional tax is imposed, which can be a small percentage of the total amount of income tax being paid. Alternatively bulk consumers like industries may pay cess calculated according to the amount of water consumed.

Stealing: Even though it is unethical, stealing is carried out by industries, commercial establishments and households by bypassing a connection around the water metre or by providing a faulty water metre. Some users may obtain an illegal connection by paying a bribe to officials. Such stolen water is usually considered as a loss to avoid further inquiries and action against the water-supplying organization.

Box 1.2 Case studies of sustainable water financing

Case 1: France

Water policy preparation, legislation and regulation are funded by national budgets. Regional water agencies (*agences de l'eau*), pertaining to the major river basins, are responsible for managing water resources, which includes abstraction and discharges. Each agency has a council of consumers and other stakeholders to review and vote on expenditure. Based on abstraction and pollution, taxes are raised from water users. Revenues are distributed through *agences de bassin* for environmental improvement and water-management measures. Local authorities provide the services directly, or through companies. Investments are financed and carried out by local bodies, which can draw soft loans from central government. Water consumers pay for water through tariffs (Cap Net, 2008).

Case 2: Netherlands

Policy, administration and supervision in the water sector is the responsibility of the central government at national level while the provinces are responsible for strategic policy, management and operation, as well as supervision of the water boards and local bodies. VEWIN (the water-planning agency) charts out ten-year plans. The Dutch Water Bank is the main source of investment in the country and it will lend only to the public sector. The water boards raise revenues by collecting property taxes. Drinking water companies treat and distribute drinking water whereas municipalities are responsible for sewerage and wastewater treatment.

Globally, some 200 billion litres of bottled water are consumed, generating around 200 billion bottles of waste water. Table 1.1 shows the cost of water in some countries. Owing to the impact on the environment, the US town of Concord in Massachusetts banned the sale of bottled water in bottles containing less than 1 litre.

1.11.1 Water Treatment and Distribution

People in many parts of the world go to river banks to carry out daily activities like washing clothes (Figure 1.18), washing animals, and taking baths, exposing themselves as well as others to risk. Population growth and economic development are causing increases in water demand in agriculture, homes and industries. Semiconductor firms need huge quantity of

Table 1.1 *Cost of water.*

Sl. no.	Description	India	United States	Switzerland	Sweden	United Kingdom
1	Rainwater	Free	Free	Free	Free	Free
2	Bottled water (per litre)	Rs. 20	$ 0.5–2.0	1–4.5 sfr	14–18 Kr	40p to £3

Figure 1.18 *Village dwellers on a river bank washing cloth.*

ultraclean water and 11 out of world's 14 largest semiconductor industries are in the Asia-Pacific region, where water quality is already severely stressed. Beverage bottlers lost their operating licenses in some parts of India due to water shortages. Freshwater consumption has more than doubled globally after World War II and is likely to rise by 25% by 2030 (Wild *et al.*, 2007).

The informal sector not only supplies water through tankers to slums but also to high-rise apartments – for example, in Bangalore, India, where the sudden population explosion has increased demand for water for construction activities as well as domestic activates in the city. About 60% of Delhi's people are not served by domestic connections and receive water from tube wells with hand pumps as well as water tankers.

Depending on the nature of the project, adequate financing need not necessarily guarantee sustainability. Southern Nevada Water Authority (SNWA) intends to supply 11 billion gallons water to urban dwellers from rural north-eastern Nevada, about 300 miles away despite opposition from Clark County farmers and conservationists. The water pumped to Las Vegas under the proposal does not sustain the city's annual growth and 40 million annual visitors (Sweet, 2008). The Southern Nevada Water Authority plans to finance project with tax-exempt bonds but the bonds may present long-term risks due to (i) significant environmental concerns, (ii) Clark County farmers and conservationists feel that there are high energy costs in withdrawing the water and pumping and (iii) water pumped will not sustain the city's annual growth and visitors (Morrison *et al.*, 2009).

In general, a reverse osmosis (RO)-based water-treatment system is most commercially available especially in the developed countries. It consists of a multistage process that involves both pretreatment and post-treatment stages in addition to an RO spiral-wound membrane module. Typical pretreatment stages involve sediment filters or microfilters and activated carbon. Meanwhile, post-treatment stages will include activated carbon filters. Such systems are placed on a table top or under a sink system. They are normally installed in order to purify tap water coming from water supply. The system can work perfectly

without the use of electricity; the pressure will be provided by feed tap water in the system. The maintenance in most cases will be the replacement of pre- and postfilters once in 16–18 months. The membrane lifetime is expected to be 2–3 years, depending on the quality of tap water. The price for such system varies according to the flow rate in the range from US$ 200 to 700. Furthermore, their annual operating costs are approximately US$ 85–135.

In general, such RO-based water treatment systems with multistage pre- and post-treatment required expensive installations that need service and parts replacement and a good-quality water source. Due to these factors this system may not be applicable in poor countries even if it is widely used in developed countries.

The 'ROSI' system was developed by Schafer and Richards (2005), which is an RO-based system designed independently without the use of an energy source. This system treats water from different types of water sources, ranging from highly turbid surface waters to highly saline brackish. The process involves two stages: a pretreatment stage using ultrafiltration (UF) membrane followed by a desalination stage, which uses either an RO or nanofilter membrane. The function of a UF membrane is to remove most pathogens, such as bacteria, particles and some colloidal material; in this way the RO/NF membrane is protected from excessive biofouling and the cleaning frequency of the modules is reduced (Schafer and Richards, 2005). It is equipped with photovoltaic or solar modules and the ROSI system may be used independently of any energy source in regions with high sunshine intensity. This system has been tested in remote rural areas in Australia. However, there are no published data on the costs of this system. The equipment is relatively complex, which includes UF, RO/NF and photovoltaic modules. Hence the investment costs are high and maintenance would require skilled personnel.

Most water-quality problems are due to the presence of pathogens, which are completely removed by ultrafiltration membranes. Reverse osmosis membranes require much higher pressures than UF membranes due to higher resistance and also because RO generates osmotic pressure, which counteracts the water transported through the membrane (Peter-Varbanets *et al.*, 2009).

Many commercially produced microfiltration filters are for travellers' use.

Another newly implemented microfiltration application is the 'filter pen', operated by sucking raw water through a strawlike device, which is actually a microfiltration membrane. The membrane has an average pore size of 0.15 μm and a surface area of 0.02 m^2. According to the manufacturer's data, initial clean water flow rates are about 0.1 l/min at a pressure difference of 0.1 bar. Depending on the quality of the feed water, the service life of the filter pen is approximately 4 weeks or 100 litres of treated water, which is equal to a water production of about 3.5 l/day.

The use of membrane systems has increased significantly, especially for water and wastewater treatment (Peter-Varbanets *et al.*, 2009). Although this technology has become more efficient and the costs of the membranes have decreased significantly (Churchouse and Wildgoose, 1999), it remains unaffordable for the world's poorest. Previous research has shown that research into, and development of, membrane systems aimed specifically for the developed countries remains limited to isolated cases (Wessels, 2000; Pillay and Buckley, 2003; Goldie *et al.*, 2004) and is often not published in the available literature (Peter-Varbanets *et al.*, 2009), although this is important to ensure that the knowledge/skills in developing these systems is not restricted to a few individuals or groups or companies.

1.11.2 Wastewater Treatment, Collection and Disposal

Despite the Millennium Development Goal (MDG) targets and the increase in awareness about sanitation, financial commitment is lacking. Despite the understanding that an adequate and reliable sanitation service is essential to improve health, urban and rural settlements are largely unsuccessful in meeting basic needs. Each sanitation facility will cost nearly the price of a cow (or ten piglets or four sheep), which is not attractive to a villager (Chandrappa and von Munch, 2008). Hence, poor people in rural settlements would opt for open defecation, thereby spreading pathogens. Total bilateral aid for water as well as sanitation from the major OECD donors was 25% lower in 2001 and 2002 compared to 1998 and 1999 (GTZ, 2006). Due to the failure to prioritize the water supply and sanitation in national development perceptions, the sector has to compete with other sectors and it does so with only limited success due to low recognition of its importance. The sector is therefore frequently underfunded. In sub-Saharan Africa, East Asia, South Asia and the Pacific, less than 50% of the population has access to sanitation. Central Europe, Eastern Europe, Latin America and Caribbean have the maximum rates of access to sanitation.

Apart from pollution due to poor sanitation, pollution from industries is posing a major challenge especially that from small- and medium-scale industry. In many parts of the world, sourcing goods and services, small- and medium-scale industries are economically attractive as they are operated and owned by entrepreneurs, thereby reducing expenditure on manpower and overheads. Such industries also contribute to water contamination as they try to cut down the costs of pollution-control activities as well (Figures 1.19 and 1.20).

On the other hand, the organic compounds produced by the petroleum and other chemical industries can contaminate sites and leach to groundwater. These chemicals are persistent and have low solubility; light ones float on the water table and heavy ones will move down to bedrock and form a no aqueous phase liquid (NAPL). BTEX, composed of benzene, toluene, ethyl benzene and xylene, is a basic petroleum derivative that can be found as a groundwater contaminant.

Figure 1.19 *Wastewater is being drained out without treatment from a small-scale industry.*

Figure 1.20 *Oil spillage in a waste-oil storage yard.*

1.12 Legal Aspects

Legislation related to the environment and the conservation of natural water quality was enacted for the first time in many countries all over the world after United Nations Conference on the Human Environment held in Stockholm in 1972. Even though the implementation of these laws has not been as thorough in the developing countries, the situation is far better than in 1972, which has been a cause for hope in every country. Even though laws are flouted in many countries, activism by nongovernmental organizations (NGOs) and public-interest litigation in many parts of the world have restored confidence among citizens. Legislation related to water conservation will typically have the following: (i) objectives, (ii) institutional arrangements, (iii) institutional responsibilities, (iv) enforcement mechanisms, (v) standards for effluent and natural water bodies.

Responsibilities are often twofold: (i) administrative and (ii) enforcement. Administrative aspects include recruitment, the academic qualification of officers and staff, salary structure, budgeting responsibility, delegation of financial powers and so on. Enforcement usually involves filing cases, issuing closure orders, issuing permits and cutting down essential services like power/fuel/water.

Legal enforcement can be proactive or relative. Proactive approaches include prohibition of certain activities in certain areas, protecting sensitive areas/water bodies, protecting catchment areas and so on. Reactive approaches include lodging complaints/bringing cases in courts of law, giving direction to polluting units, giving direction to organizations that are providing essential services to stop services. Essential services include water/fuel/electric supplies, securities, loans and so on.

In many instances, failures of environmental laws (Figure 1.21) occur due to ignorance by the enforcing agency or too much knowledge amongst the polluters about loopholes in the law. Usually the government will protect the interest of polluters as they are a source of funds in democratic countries. Officers of the enforcing agency will often be used for purposes other than pollution control, like election duty, work related to national festivals and personal work by people's representatives and people in power. Too much time on paperwork, low work ethics, poor record-keeping practice and lack of decision-making ability in top

Figure 1.21 *Reasons for failure of environmental legislation.*

management also sometimes lead to the weakening of organizations' ability to deliver their objectives. Many of the developing countries will have poor manpower due to the inability of organizations to recruit eligible candidates or because of pressure from politicians. Some environmental protection organizations are bogged down with indiscipline and disputes among the staff.

External interference still dominates in many environmental protection organizations and staff are unable to update their knowledge about court verdicts, new policies due to international law and local legislation. It is often considered that family members of higher officials are more important than people who work in the organization. Use of vehicles, infrastructure and funds by political leaders, higher officials and their family members for private purposes has been a cause of a decline in morals amongst the staff in public organizations.

Holidays and nights are most often used by polluters and officers are often distracted by false complaints. The media attach greater importance to sports and glamorous events than to environmental issues and this has also often distracted ruling representatives. In many cases political leaders will be unable to see beyond the next election and hence they prioritize local issues that can bring them more votes than long-term environmental protection. Free electricity and loan waivers have resulted in the depletion of groundwater due to excessive drilling of bore wells and siphoning of ground water. The use of excessive agrochemicals and encouragement of industries has also caused environmental deterioration in many developing countries.

As per Shapiro *et al.* (2009), the five 'protector agencies' in the United States – Food and Drug Administration, the Occupational Safety and Health Administration, the Consumer Product Safety Commission, the National Highway Traffic Safety Administration and the Environmental Protection Agency – grapple with their responsibility to protect the American public from hazards. The agencies' inability to act swiftly and decisively in recent decades is largely the result of severe shortfalls in funding, political interference, outdated authorizing statutes and an ageing, demoralized civil service (Shapiro *et al.*, 2009).

Rapid urbanization due to poor migration policies and job creation has led to poor urban planning. In many instances, industries established within the city in previous decades continue to operate while new residential apartments are established, leading to clashes in the community. Too much emphasis by financial planners on increasing gross domestic product (GDP) has led to urbanization being prioritized over improvements in the rural economy. Establishment of industrial areas is often considered the only way to improve the economy rather than preserving the environment and water quality. As a result deteriorating heath due to a poor environment and waterborne diseases has led to an increase in GDP due to burgeoning medical expenditure and strengthening of pharmaceutical sector. The deteriorating water quality has also led to an increase in sales of bottled water across the globe, thereby contributing to GDP.

Unsafe working conditions due to terrorism or workplace harassment have also resulted in poor performance by environmental protection organizations in many countries. The absence of transparency where it is required (as in decision making) and the absence of confidentiality in certain situations (like drafting legal cases against defaulters) have also been reasons for failure of enforcement in many situations.

According to Pallangyo (2007) there are over 50 principal laws in Tanzania related to environmental issues and many of these laws are outdated, not understood and overlap in terms of functional authority. Most of these laws fail to induce compliance since the *ex ante* value of the penalties is far below the compliance cost. As per Pistone (2010) at least 103 children in Toms River, located in Dover Township, New Jersey in the United States, had been diagnosed with cancer and problem is that the loopholes in the laws concerning how remediation is carried out rely greatly on agencies' discretion.

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