Chapter 1

INTRODUCTION TO ENVIRONMENTAL ENGINEERING

1.1 Environmental Engineering

Environmental engineering concerns with the environment and management of natural resources is a relatively new profession with a long and honorable history. This places special attention on biological, chemical and physical reactions in the air, land and water environment around us and on improved technologies for minimizing its degradation with improved management system including reuse, recycling and recovery measures to provide healthy air, land and water for human habitation, plants, animals and all other living organisms. Although the environmental engineering began with consideration of the need for pure drinking water and management of liquid and solid wastes, eventually abetment of air and land contamination along with management of toxic and hazardous wastes became new challenges. The protection of wildlife habitat, preservation of species and the overall well-being of ecosystems are also the major concerns. The descriptive title of "environmental engineer" was not used until the 1960s, when academic programs in engineering and public health schools broadened their scope and required a more accurate title to describe their curricula and their graduates. The roots of this profession, however, go back as far as recorded history. These roots reach into several major disciplines including civil engineering, sanitary engineering, public health, ecology, chemistry, and meteorology. From each foundation, the environmental engineering profession draws knowledge, skill, and professionalism. From ethics, the environmental engineer draws concern for the greater good.

1.1.1 Background of civil and environmental engineering

Throughout western civilization settled agriculture and the development of agricultural skills created a cooperative social fabric and spawned the growth of communities, as well as changed the face of the earth with its overriding impact on the natural environment. As farming efficiency increased, a division of labor became possible, and communities began to build public and private structures that engineered solutions to specific public problems. Defense of these structures and of the land became paramount, and other structures subsequently were built purely for defensive purposes. In some societies the conquest of neighbors required the construction of machines of war. Builders of war machines became known as engineers, and the term "engineer" continued to imply military involvement well into the eighteenth century. The earliest practise of civil engineering may have commenced between 4000 and 2000 BC in Ancient Egypt and Mesopotamia (Ancient Iraq) when humans started to abandon a nomadic existence, thus causing a need for the construction of shelter. During this time, transportation became increasingly important leading to the development of the wheel and sailing.

In 1782 John Smeaton, builder of roads, structures, and canals in England, recognized that his profession tended to focus on the construction of public facilities rather than purely military ones, and that he could correctly be designated a civil engineer. This title was widely adopted by engineers engaged in public works (Kirby, Withington et al. 1956).

In 1818 the Institution of Civil Engineers was founded in London, and in 1820 the eminent engineer Thomas Telford became its first president. The institution received a Royal Charter in 1828, formally recognising civil engineering as a profession.

The first formal university engineering curriculum in the United States was established at the U.S. Military Academy at West Point in 1802. The first engineering course outside the Academy was offered in 1821 at the American Literary, Scientific, and Military Academy, which later became Norwich University. The Renssalaer Polytechnic Institute conferred the first truly civil engineering degree in 1835. In 1852, the American Society of Civil Engineers was founded (Wisely 1974). Ever since people first recognized that their health and well-being were related to the quality of their environment, they have applied thoughtful principles to attempt to improve the quality of their environment. The ancient Harappan civilization utilized early sewers in some cities. The Romans constructed aqueducts to prevent drought and to create a clean, healthful water supply for the metropolis of Rome. In the 15th century, Bavaria created laws restricting the development and degradation of alpine country that constituted the region's water supply. The field emerged as a separate environmental discipline during the middle third of the 20th century in response to widespread public concern about water and pollution and increasingly extensive environmental quality degradation. However, its roots extend back to early efforts in public health engineering.

Water supply and wastewater drainage were among the public facilities designed by civil engineers to control environmental pollution and protect public health. The availability of water had always been a critical component of civilizations. Ancient Rome, for example, had water supplied by nine different aqueducts up to 80 km (50 miles) long, with cross sections from 2 to 15 m (7 to 50 ft). The purpose of the aqueducts was to carry spring water, which even the Romans knew was better to drink than Tiber River water.

As cities grew, the demand for water increased dramatically. During the eighteenth and nineteenth centuries the poorer residents of European cities lived under abominable conditions, with water supplies that were grossly polluted, expensive, or nonexistent. In London the water supply was controlled by nine different private companies and water was sold to the public. People who could not afford to pay for water often begged or stole it. During epidemics of disease the privation was so great that many drank water from furrows and depressions in plowed fields. Droughts caused water supplies to be curtailed and great crowds formed to wait their "turn" at the public pumps (Ridgway 1970).

The first public water supply system consisted of wooden pipes, bored and charred, with metal rings shrunk on the ends to prevent splitting was installed in 1652, and the first citywide system was constructed in Winston-Salem, NC, in 1776. One of the first major water supply undertakings was the Croton Aqueduct, started in 1835 and completed six years later. This engineering marvel brought clear water to Manhattan Island, which had an inadequate supply of groundwater (Lankton 1977).

The earliest known acknowledgment of the effect of impure water is found in Susruta Samhitta, a collection of fables and observations on health, dating back to 2000 BCE, which recommended that water be boiled before drinking. Water filtration became commonplace toward the middle of the nineteenth century. The first successful water supply filter was in Parsley, Scotland, in 1804, and many less successful attempts at filtration followed(Baker 1949). The use of alum to clarify water was proposed in 1757, but was not convincingly demonstrated until 1885. Disinfection of water with chlorine began in Belgium in 1902 and in America, in Jersey City, NJ, in 1908. Between 1900 and 1920 deaths from infectious disease dropped dramatically, owing in part to the effect of cleaner water supplies.

Human waste disposal in early cities presented both a nuisance and a serious health problem. Often the method of disposal consisted of nothing more than flinging the contents of chamberpots out the window (Figure1.1). Around 1550, King Henri II repeatedly tried to get the Parliament of Paris to build sewers, but neither the king nor the parliament proposed to pay for them. The famous Paris sewer system was built under Napoleon B(I), in the nineteenth century (De Camp 1963).

Stormwater was considered the main "drainage" problem, and it was in fact illegal in many cities to discharge wastes into the ditches and storm sewers. Eventually, as water supplies developed, the storm sewers were used for both sanitary waste and stormwater. Such "combined sewers" existed in some of our major cities until the 1980s.

The first system for urban drainage in America was constructed in Boston around 1700. There was surprising resistance to the construction of sewers for waste disposal. Most American cities had cesspools or vaults, even at the end of the nineteenth century. The most economical means of waste disposal was to pump these out at regular intervals and cart the waste to a disposal site outside the town. Engineers argued that although sanitary sewer construction was capital intensive, sewers provided the best means of wastewater disposal in the long run. Their argument prevailed, and there was a remarkable period of sewer construction between 1890 and 1900.

The first separate sewerage systems in America were built in the 1880s in Memphis, TN, and Pullman, IL. The Memphis system was a complete failure. It used small pipes that were to be flushed periodically. No manholes were constructed and cleanout became a major problem. The system was later removed and larger pipes, with manholes, were installed (AWWA 1976).

Figure 1.1: **Human waste disposal from an old woodcut (Baker 1949)**

Initially, all sewers emptied into the nearest watercourse, without any treatment. As a result, many lakes and rivers became grossly polluted and, as an 1885 Boston Board of Health report put it, "larger territories are at once, and frequently, enveloped in an atmosphere of stench so strong as to arouse the sleeping, terrify the weak and nauseate and exasperate everybody."

Wastewater treatment first consisted only of screening for removal of the large floatables to protect sewage pumps. Screens had to be cleaned manually, and wastes were buried or incinerated. The first mechanical screens were installed in Sacramento, CA, in 1915, and the first mechanical comminutor for grinding up screenings was installed in Durham, NC. The first complete treatment systems were operational by the turn of the century, with land spraying of the effluent being a popular method of wastewater disposal.

Civil engineers were responsible for developing engineering solutions to these water and wastewater problems of these facilities. There was, however, little appreciation of the broader aspects of environmental pollution control and management until the mid-1900s. As recently as 1950 raw sewage was dumped into surface waters in the United States and even streams in public parks and in U.S. cities were fouled with untreated wastewater. The first comprehensive federal water pollution control legislation was enacted by the U.S. Congress in 1957, and secondary sewage treatment was not required at all before passage of the 1972 Clean Water Act. Concern about clean water has come from the public health professions and from the study of the science of ecology.

Briefly speaking, the main task of environmental engineers is to protect public health by protecting (from further degradation), preserving (the present condition of), and enhancing the environment. Also, they develop new forms of energy and ways to increase the efficiency of generating and using energy. They try to get people to convert to environmental friendly energy and products.

1.2 Sanitary Engineering

It traditionally include application of engineering methods to improve sanitation of human communities mostly supplying potable water and removing (both solid and liquid) wastes for final disposal but had not include much of the hazardous waste management and environmental remediation works, Skills within this field are usually employed for the primary goal of disease prevention within human beings.

1.3 Public Health

Public health is the science and art of preventing disease, prolonging life and promoting health through the organized efforts and informed choices of society, organizations, public and private, communities and individuals. It is concerned with threats to health based on population health analysis. The focus of public health intervention is to improve health and quality of life through the prevention and treatment of disease and other physical and mental health conditions, through surveillance of cases and the promotion of healthy behaviours. Therefore, the motto of public health is 'prevention is better than cure'.

The concerns of public health encompass not only water but all aspects of civilized life, including food, air, toxic materials, noise, and other environmental insults. The work of the environmental engineer has been made more difficult by the current tendency to ascribe many ailments, including psychological stress, to environmental origins, whether or not there is any evidence linking cause and effect. The environmental engineer faces the rather daunting task of elucidating such evidence relating causes and effects that often are connected through years and decades as human health and the environment respond to environmental pollutants.

1.4 Ecology and Environment

Ecology includes the study of plant and animal populations, plant and animal communities and ecosystems. Ecosystems describe the web or network of relations among organisms at different scales of organization. Ecologists study everything from the role of bacteria in nutrient recycling to the effects of tropical rain forest on the Earth's atmosphere. The discipline of ecology emerged from the natural sciences in the late 19th century. Ecology is not synonymous with environment, environmentalism, or environmental science. Ecology is closely related to the disciplines of physiology, evolution, genetics and behavior.

Like many of the natural sciences, a conceptual understanding of ecology is found in the broader details of study, including:

- life processes explaining adaptations
- distribution and abundance of organisms
- the movement of materials and energy through living communities
- the successional development of ecosystems, and

- the abundance and distribution of biodiversity in context of the environment.

Ecology is distinguished from natural history, which deals primarily with the descriptive study of organisms. It is a sub-discipline of biology, which is the study of life. There are many practical applications of ecology in conservation biology, wetland management, natural resource management (agriculture, forestry, fisheries), city planning (urban ecology), community health, economics, basic & applied science and it provides a conceptual framework for understanding and researching human social interaction (human ecology).

Although we often draw lines around a specific ecosystem to be able to study it more fully (e.g., a farm pond) and thereby assume that the system is completely self-contained, this is obviously not me. One of the tenets of ecology is that "everything is connected with everything else." Three categories of organisms make up an ecosystem. The producers use energy from the sun and nutrients like nitrogen and phosphorus from the soil to produce highenergy chemical compounds by the process of photosynthesis. The energy from the sun is stored in the molecular structure of these compounds. Producers are often referred to as being in the first trophic (growth) level and are called autotrophs. The second category of organisms in an ecosystem includes the consumers, who use the energy stored during photosynthesis by ingesting the high-energy compounds. Consumers in the second trophic level use the energy of the producers directly. There may be several more trophic levels of consumers, each using the level below it as an energy source. A simplified ecosystem showing various trophic levels is illustrated in Figure 1.2, which also shows the progressive use of energy through the trophic levels. The third category of organisms, the decomposers or decay organisms, use the energy in animal wastes, along with dead animals and plants, converting the organic compounds to stable inorganic compounds (e.g., nitrate) that can be used as nutrients by the producers. Ecosystems exhibit a flow of both energy and nutrients. The original energy source for nearly all ecosystems is the sun (the only notable exception is oceanic hydrothermal vent communities, which derive energy from geothermal activity). Energy flows in only one direction: from the sun and through each trophic level. Nutrient flow, on the other hand, is cyclic: nutrients are used by plants to make high-energy molecules that are eventually decomposed to the original inorganic nutrients, ready to be used again.

Most ecosystems are sufficiently complex that small changes in plant or animal populations will not result in long-term damage to the ecosystem. Ecosystems are constantly changing, even without human intervention, so ecosystem stability is best defined by its ability to return to its original rate of change following a disturbance. For example, it is unrealistic to expect to find the exact same numbers and species of aquatic invertebrates in a "restored" stream ecosystem as were present before any disturbance. Stream invertebrate populations vary markedly from year to year, even in undisturbed streams. Instead, we should look for the return of similar types of invertebrates, in about the same relative proportion as would be found in undisturbed streams. The amount of perturbation that an ecosystem can absorb is called resistance. Communities dominated by large, long-lived plants (e.g., old growth forests) tend to be fairly resistant to perturbation (unless the perturbation is a chain saw!) Ecosystem resistance is partially based on which species are most sensitive to the particular disturbance. Even relatively small changes in the populations of "top of the food chain" predators (including humans) or critical plant types (e.g., plants that provide irreplaceable habitat) can have a substantial impact on the structure of the ecosystem. The ongoing attempt to limit the logging of old-growth forests in the Pacific Northwest is an attempt to preserve critical habitat for species that depend on old growth, such as the spotted owl and the marbled murmlet. The rate at which the ecosystem recovers from perturbation is called resilience. Resilient ecosystems are usually populated with species that have rapid colonization and growth rates. Most aquatic ecosystems are very resilient (but not particularly resistant). For example, during storm events, the stream bottom is scoured, removing most of the attached algae that serve as food for small invertebrates. The algae grow quickly after the storm flow abates, so the invertebrates do not starve. In contrast, the deep oceanic ecosystem is extraordinarily fragile, not resilient, and not resistant to environmental disturbances. This must be considered before the oceans are used as waste repositories.

Although inland waters (streams, lakes, wetlands, etc.) tend to be fairly resilient ecosystems, they are certainly not totally immune to destruction by outside pesticides, and synthetic organic compounds, one of the most serious effects of pollutants on inland waters is depletion of dissolved oxygen. All higher forms of aquatic life exist only in the presence of oxygen, and most desirable microbiologic life also requires oxygen. Natural streams and lakes are usually aerobic. If a watercourse becomes anaerobic, the entire ecology changes and the water become unpleasant and unsafe. The dissolved oxygen concentration in waterways and the effect of pollutants are closely related to the concept of decomposition and biodegradation, part of the total energy transfer system that sustains life.

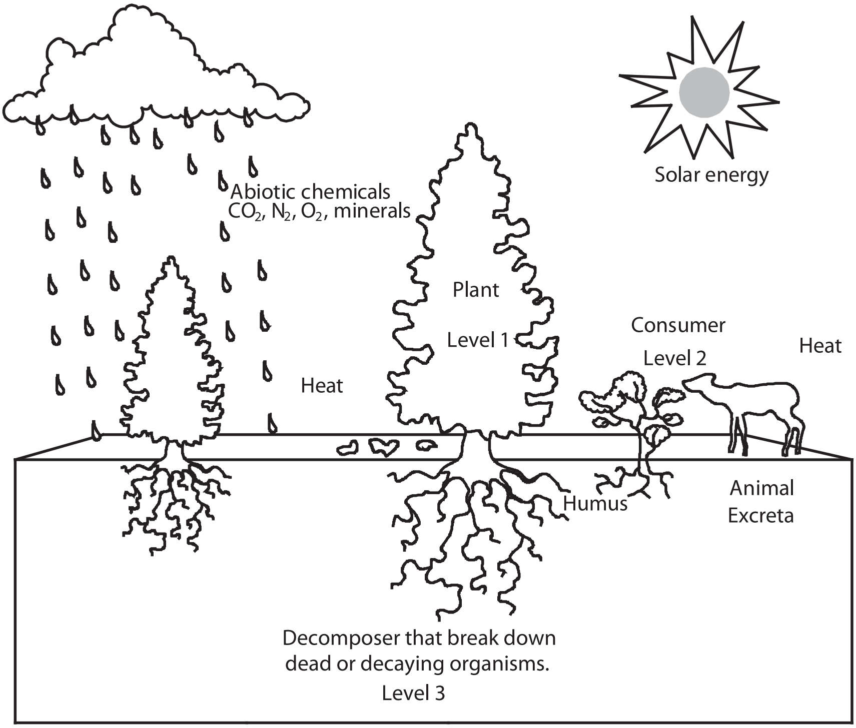


Figure 1.2: **A typical terrestrial ecosystem**

1.4.1 Populations of ecology

The populations of the species in an ecosystem do not vary independently but rather fluctuate in an approximate steady state in response to self-regulating or negative feedback (homeostasis). Homeostatic equilibrium is dynamic, however, because the populations are also governed by positive feedback mechanisms that result from changes in the physical, chemical, and biological environment (homeorhesis).

Homeostatic mechanisms can be illustrated by a simple interaction between two populations, such as the HARE and the LYNX populations pictured in Figure 1.3. When the HARE population is high the LYNX have an abundant food supply and procreate. The LYNX population increases until the LYNX outstrip the available HARE population. Deprived of adequate food, the LYNX population then decreases, while the HARE population increases because there are fewer predators. This increase, in turn, provides more food for the LYNX population, and the cycle repeats. The numbers of each population are continually changing, making the system dynamic. When studied over a period of time, the presence of this type of self-regulating feedback makes the system appear to be in a steady state, which we call homeostasis.

In reality, populations rarely achieve steady state for any extended period of time. Instead, populations respond to physical, chemical, and biological changes in the environment along a positive feedback trajectory that will eventually settle into a new, but again temporary, homeostasis. Some of these changes are natural (e.g., a volcanic eruption that covers the LYNX and HARE habitat with ash or molten rock); many are caused by humans (e.g., destruction or alteration of habitat, introduction of competing species, trapping or hunting).

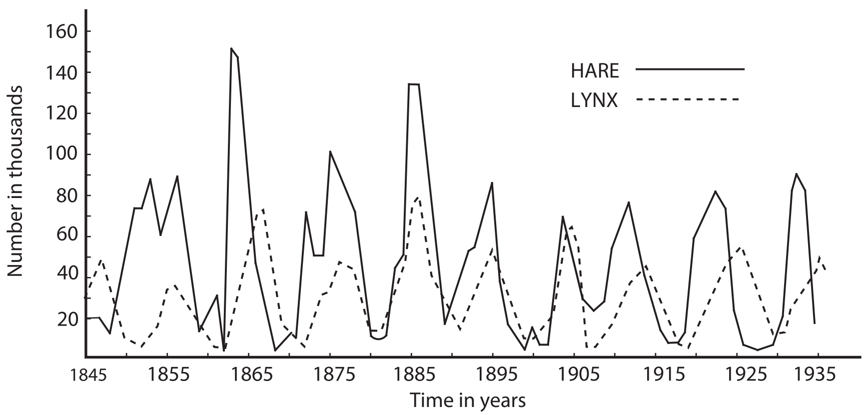


Figure 1.3: **Homeostatic mechanisms**

Ecosystem interactions obviously can also include more than two species; consider, for example, the sea otter, the sea urchin, and kelp in a homeostatic interaction. The kelp forests along the Pacific coast consist of 60m (200ft) streamers fastened to the ocean floor. Kelp can be economically valuable, since it is the source of algin used in foods, paints, and cosmetics. In the late 1900s kelp began to disappear mysteriously, leaving a barren ocean floor. The mystery was solved when it was recognized that sea urchins feed on the kelp, weaken the stems, and cause them to detach and float away. The sea urchin population had increased because the population of the predators, the sea otters, had been reduced drastically. The solution was protection of the sea otter and increase in its population, resulting in a reduction of the sea urchin population and maintenance of the kelp forests.

Some ecosystems are fragile, easily damaged, and slow to recover; some are resistant to change and are able to withstand even serious perturbations; and others are remarkably resilient and able to recover from perturbation if given the chance. Engineers must consider that threats to ecosystems may differ markedly from threats to public health; for example, acid rain poses a considerable hazard to some lake ecosystems and agricultural products, but virtually no direct hazard to human health. A converse example is that carcinogens dispersed in the atmospheric environment can enter the human food chain and be inhaled, putting human health at risk, but they could pose no threat to the ecosystems in which they are dispersed.

Engineers must appreciate the fundamental principles of ecology and design in consonance with these principles in order to reduce the adverse impacts on fragile ecosystems. For example, since the deep oceans are among the most fragile of all ecosystems this fragility must be part of any consideration of ocean disposal of waste. The engineer's job is made even harder when he or she must balance ecosystem damage against potential human health damage. The inclusion of ecological principles in engineering decisions is a major component of the environmental engineering profession.

1.5 Biodegradation

Plant growth, or photosynthesis, may be represented by the equation:

$$6CO_2 + 12H_2O + light + C_6H_{12}O_6 + 6H_2O + 6O_2 \qquad 1.1$$

In this simplified example, glucose ($C_6H_{12}O_6$) water (H_2O), and oxygen (O_2) are produced from carbon dioxide (CO_2) and water, with sunlight as the source of energy and chlorophyll as a catalyst. Photosynthesis is basically a redox reaction where CO_2 is reduced to glucose or other high-energy carbon compounds of the general form HCOH, using water as the hydrogen donor. When glucose is metabolized (used as food), by the plant cell or by an animal consumer, energy is released in much the same way as in burning any fuel, with the end products being heat, carbon dioxide, and water.

In addition to sunlight, CO_2 and H_2O, plants require inorganic nutrients, particularly nitrogen and phosphorous, to grow. Equation (1.2) shows that production of algal protoplasm (the living portion of an algae cell) requires a ratio of 106 units of carbon and 16 units of nitrogen for every unit of phosphorus:

$$106CO_2 + 16NO_3^- + HPO_4^{2-} + 122H_2O + 18H^+ \rightarrow [(CH_2O)_{106}(NH_3)_{16}(H_3PO_4)] \quad 1.2$$

As discussed previously, plants (producers) use inorganic nutrients and sunlight as an energy source to build high-energy compounds. Consumers eat and metabolize these compounds, releasing some of the energy for the consumer to use. The end product of metabolism (excrement) becomes food for decomposers and is degraded further, but at a much slower rate because many of the readily digestible compounds have already been consumed. After several such steps, only very low-energy compounds remain, and decomposers can no longer use the residue as food. Plants then use these compounds to build more high-energy compounds by photosynthesis, and the process starts over. The process is shown symbolically in Figure 1.4 Many organic materials responsible for water pollution enter watercourses at a high energy level. The biodegradation or gradual use of energy, of the compounds by a chain of organisms causes many water pollution problems.

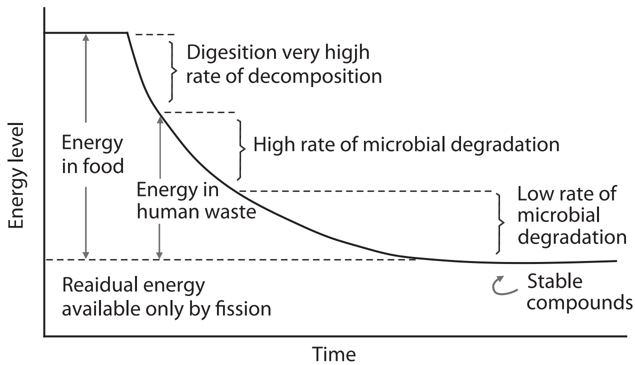


Figure 1.4: **Energy loss in biodegradation. (De Camp 1963)**

1.6 Aerobic and Anaerobic Decomposition

Decomposition or biodegradation may take place in one of two distinctly different ways: aerobic (using free oxygen) and anaerobic (in the absence of free oxygen). The basic equation for aerobic decomposition of complex organic compounds is:

$$HCOH + O_2 + CO_2 + H_2O + energy \quad 1.3$$

The biological respiration or decomposition of glucose (the reverse of Eq. (1.1)) under aerobic conditions would result in the release of CO_2, H_2O, and energy that can be used for metabolism:

$$C_6H_{12}O_6 + 6H_2O + 6CO_2 + 12H_2O + \text{energy} \quad 1.4$$

Carbon dioxide and water are always two of the end products of aerobic decomposition. Both are stable, low in energy, and used by plants in photosynthesis (plant photosynthesis is a major CO_2 sink for the earth). Nitrogen, phosphorus, and sulfur compounds are often included in the general discussion of decomposition because the breakdown and release of these compounds during decomposition of organic matter can contribute to water quality problems. In aerobic environments, sulfur compounds are oxidized to the sulfate ion (SO_4^{2-}) and phosphorus is oxidized to phosphate (PO_4^{3-}). Any phosphate not rapidly taken up by microorganisms is bound by physical or chemical attraction to suspended sediments and metal ions, making it unavailable to most aquatic organisms. Nitrogen is oxidized through a series of steps in the progression:

$$\text{Organic N} \rightarrow NH_3 \text{ (ammonia)} + NO_2^- \text{ (nitrite)} + NO_3^- \text{ (nitrate)}$$

Because of this distinctive progression, various forms of nitrogen are used as indicators of water pollution. A schematic representation of the aerobic cycle for carbon, nitrogen, sulfur, and phosphorus is shown in Figure 1.5. This figure shows only the basic phenomena and greatly simplifies the actual steps and mechanisms. Anaerobic decomposition is usually performed by a completely different set of microorganisms, to which oxygen may even be toxic. (Microorganisms that can only survive in anaerobic environments are called obligate anaerobes; facultative anaerobes can survive in aerobic or anaerobic environments.) The basic equation for anaerobic biodegradation is

$$2HCOH \rightarrow CH_4 + CO_2 + \text{energy} \quad (1.5)$$

Figure 1.6 is a schematic representation of anaerobic decomposition. Note that the left half of the cycle, photosynthesis by plants, is identical to the aerobic cycle. Many of the end products of anaerobic decomposition are biologically unstable. Methane (CH_4) for example, is a high-energy gas commonly called "marsh gas" (or "natural gas" when burned as fuel). Although methane is physically stable (does not break down spontaneously), it can be oxidized and used as an energy source (food) by a variety of aerobic bacteria. Ammonia (NH_3) can also be oxidized by aerobic bacteria or used by plants as a nutrient. Sulfur is anaerobically biodegraded to evil smelling sulfhydryl compounds like hydrogen sulfide (H_2S), and can be used as an energy source by aerobic bacteria. Phosphates released during anaerobic decomposition are very soluble in water and do not bind to

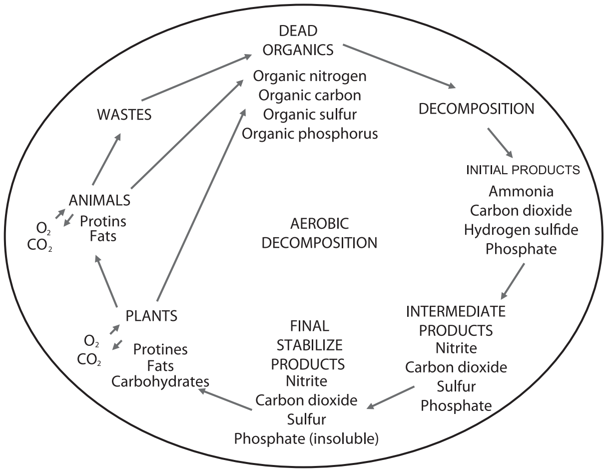


Figure 1.5: **Aerobic carbon, nitrogen, phosphorus, and sulfur cycles. (De Camp 1963)**

metal ions or sediments. Soluble phosphate is easily taken up by plants and used as a nutrient. Biologists often speak of certain compounds as hydrogen acceptors. When energy is released from high-energy compounds a C=H or N=H bond is broken, and the freed hydrogen must be attached somewhere. In aerobic decomposition, oxygen serves the purpose of a hydrogen scavenger or hydrogen acceptor, and forms water. In anaerobic decomposition, oxygen is not available. The next preferred hydrogen acceptor is nitrate (NH_3^-) or nitrite (NO_2^-), forming ammonia (NH_3). If no appropriate nitrogen compound is available, sulfate

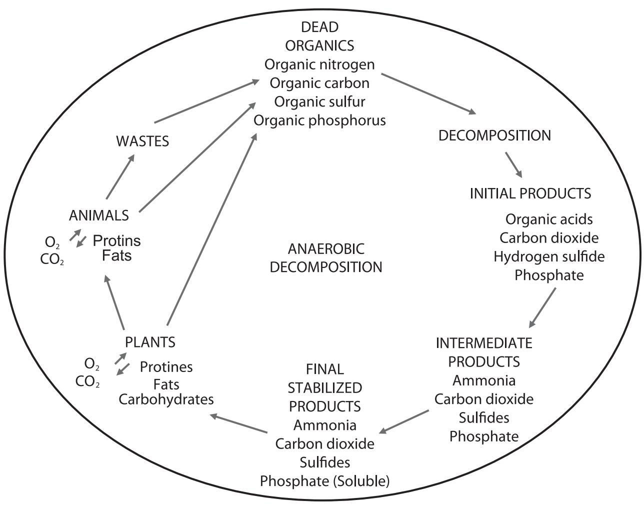


Figure 1.6: **Anaerobic carbon, nitrogen, phosphorus, and sulfur cycles.**

(SO_4^{2-}) accepts hydrogen to form sulfur (S) and H_2S, the compound responsible for the notorious rotten egg smell.

1.7 Climate Change

The most general definition of climate change is a change in the statistical properties of the climate system when considered over long periods of time, regardless of cause, this type of climate change and its effects have been documented in the past. The term sometimes is used to refer specifically to climate change caused by human activity; for example, the United Nations Framework Convention on Climate Change defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods." In this later sense, used especially in the context of environmental policy, climate change is synonymous with anthropogenic global and natural warming.

1.7.1 Green house gases and its effect

Life on Earth depends on energy coming from the sun. About half the light reaching Earth's atmosphere passes through the air and clouds to the surface, where it is absorbed and then radiated upward in the form of infrared heat (Figure 1.7). A layer of greenhouse gases – primarily water vapor, and including much smaller amounts of carbon dioxide, methane and nitrous oxide – act as a thermal blanket for the Earth. About 90 percent of this heat is then absorbed by the greenhouse gases and radiated back toward the surface, which is warmed to a life-supporting average of 59 °F (15°C).

The greenhouse effect is a natural warming process. Carbon dioxide (CO_2) and certain other gases are always present in the atmosphere. These gases create a warming effect that has some similarity to the warming inside a greenhouse, therefore the name "greenhouse effect". On the other hand, amplified warming is the amount of greenhouse gases that intensifies the greenhouse effect. Higher concentrations of CO_2 and other greenhouse gases trap more infrared energy in the atmosphere than occurs naturally. The additional heat further warms the atmosphere and Earth's surface.

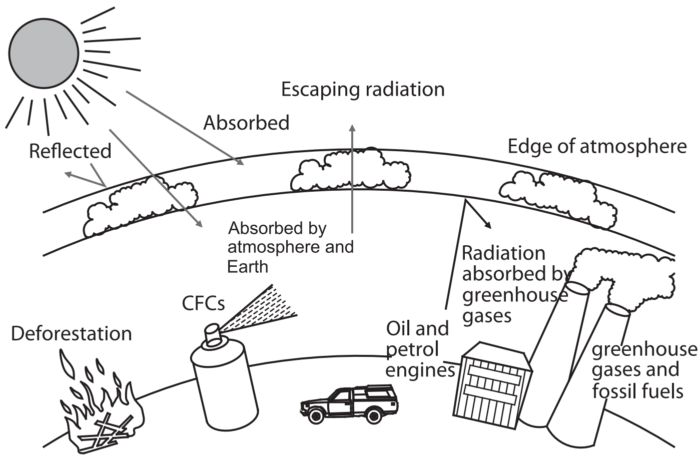


Figure 1.7: Effect of greenhouse gases

1.7.2 Causes of climate change

The natural variability and the climate fluctuations of the climate system have always been part of the Earth's history however there have been changes in concentrations of greenhouse gases in the atmosphere growing at an unprecedented rate and magnitude. The United Nations, governments and many top scientists around the world believe that we must act now to stabilize and arrest further changes. To understand climate change fully, the causes of climate change must be first identified. Scientists divide the causes into two categories, natural and human causes.

Natural Causes of Climate Change

Factors that can shape climate are often called climate forcing. The earth's climate is influenced and changed through natural causes like volcanic eruptions, ocean current, the earth's orbital changes and solar variations.

- **Volcanic eruptions:** When a volcano erupts it throws out large volumes of sulphur dioxide (SO_2), water vapour, dust, and ash into the atmosphere. Large volumes of gases and ash can influence climatic patterns for years by increasing planetary reflectivity causing atmospheric cooling. Tiny particles called aerosols are produced by volcanoes. Because they reflect solar energy back into space they have a cooling effect on the world. The greenhouse gas, carbon dioxide is also produced however the CO_2 produced is insignificant when compared to emissions created by humans.

- **Ocean current:** The oceans are a major component of the climate system. Ocean currents move vast amounts of heat across the planet. Winds push horizontally against the sea surface and drive ocean current patterns. Interactions between the ocean and atmosphere can also produce phenomena such as El Niño which occur every 2 to 6 years. Deep ocean circulation of cold water from the poles towards the equator and movement of warm water from the equator backs towards the poles. Without this movement the poles would be colder and the equator warmer. The oceans play an important role in determining the atmospheric concentration of CO_2. Changes in ocean circulation may affect the climate through the movement of CO_2 into or out of the atmosphere.

- **Earth orbital changes:** The earth makes one full orbit around the sun each year. It is tilted at an angle of 23.5° to the perpendicular plane of its orbital path. Changes in the tilt of the earth can lead to small but climatically important changes in the strength of the seasons, more tilt means warmer summers and colder winters; less tilt means cooler summers and milder winters. Slow changes in the Earth's orbit lead to small but climatically important changes in the strength of the seasons over tens of thousands of years. Climate feedbacks amplify these small changes, thereby producing ice ages.

- **Solar variations:** The Sun is the source of energy for the Earth's climate system. Although the Sun's energy output appears constant from an everyday point of view, small changes over an extended period of time can lead to climate changes. Some scientists suspect that a portion of the warming in the first half of the 20th century was due to an increase in the output of solar energy. As the sun is the fundamental source of energy that is instrumental in our climate system it would be reasonable to assume that changes in the sun's energy output would cause the climate to change. Scientific studies demonstrate that solar variations have performed a role in past climate changes. For instance a decrease in solar activity was thought to have triggered the Little Ice Age between approximately 1650 and 1850, when Greenland was largely cut off by ice from 1410 to the 1720s and glaciers advanced in the Alps. Current global warming however cannot be explained by solar variations. Some examples are evidenced such as since 1750, the average amount of energy coming from the Sun either remained constant or increased slightly. If global warming was caused by a more active sun, then scientists would expect to see warmer temperatures in all layers of the atmosphere. They have only observed a cooling in the upper atmosphere, a warming at the surface and in the lower parts of the atmosphere. This is due to greenhouse gasses capturing heat in the lower atmosphere. Also climate models that include solar irradiance changes cannot reproduce last century's observed temperature trend without including a rise in greenhouse gases.

Human Causes of Climate Change

It is now a global concern that the climatic changes occurring today have been speeded up because of man's activities. The Industrial Revolution in the 19th century saw the large-scale use of fossil fuels for industrial activities. These industries created jobs and over the years, people moved from rural areas to the cities. This trend is continuing even today. More and more land that was covered with vegetation has been cleared to make way for houses. Natural resources are being used extensively for construction, industries, transport, and consumption. Consumerism (our increasing want for material things) has increased by leaps and bounds, creating mountains of waste. Also, our population has increased to an incredible extent. All this has contributed to a rise in greenhouse gases in the atmosphere. Fossil fuels such as oil, coal and natural gas supply most of the energy needed to run vehicles, generate electricity for industries, households, etc. The energy sector is responsible for about ¾ of the carbon dioxide emissions, $1/5$ of the methane emissions and a large quantity of nitrous oxide. It also produces nitrogen oxides (NOx) and carbon monoxide (CO) which are not greenhouse gases but do have an influence on the chemical cycles in the atmosphere that produce or destroy greenhouse gases.

1.8 Biodiversity

Biodiversity is the variation of life forms within a given ecosystem, biome, or for the entire Earth. Biodiversity is often used as a measure of the health of biological systems. Biologists most often define "biological diversity" or "biodiversity" as the "totality of genes, species, and ecosystems of a region". An advantage of this definition is that it seems to describe most circumstances and present a unified view of the traditional three levels at which biological variety has been identified:

- genetic diversity
- species diversity
- ecosystem diversity

Box 1.1

Climate Change: Perspective to Bangladesh

Bangladesh is likely the worst affected countries by climate change. This is due to its unique geographic location, hydro-geological characters like dominance of floodplains, low elevation from the sea and lastly the socio-economical characters like high population density, high levels of poverty, and overwhelming dependence on nature, its resources and services. Unfortunately, the country's future is now trapped between the melting Himalayas in the north and the encroaching Bay of Bengal to the south. The concerned sectors are mainly natural resources, agriculture and food security, infrastructure, ecosystems and biodiversity, human health and coastal zones. Hence, Climate change is not only an "environmental" concern but also economic and finally a "development" concern for Bangladesh. These may retards the targets of MDG's as well as countries target to be a middle income country by the year 2021.

Some impacts like higher temperatures, more variable precipitation and sea level rise are already being felt in Bangladesh. Eventually, there is an increasing trend in frequencies of extreme weather events including more intense floods, droughts, and storms. These will likely continue to intensify and become more severe. Alike other countries Bangladesh will suffer the global effects of climate change. Melting of ice sheets and associated sea-level rise, changes in ocean circulations salt-water intrusion, reducing fresh water supplies and increasing vector bone dangerous diseases are some of the global climate change impacts. Major disruptions associated with large-scale climate change impacts occurring elsewhere could affect Bangladesh through diverting flows of goods, services and financial resources.

Bangladesh already stressed environmentally, socially and economically. Also, the variations can be quite significant when downscaled for a location. In addition, there may be more than one impact at any given period which can lead to grave circumstances. Further, climate change induced impacts may trigger a chain of consequences due to non-climatic activities and their outcomes. Impacts of climate change can be divided into two major parts.

(a) Sea level rise: Bangladeshi scientists believe that because of sea level rise coastal Bangladesh has already experienced the worst impacts especially in terms of coastal inundation and erosion, saline intrusion, deforestation, loss of bio-diversity and agriculture, and large scale migration. About 830,000 million hectares of arable land is affected by varying degrees of soil salinity. During the period 1973–1987, about 2.18 million tons of rice was damaged due to drought and 2.38 million tons due to flood. Drought affects annually about 2.32 million hectares and 1.2 million hectares of cropped land during the Kharif (summer) (November to June) and Rabi (winter) (July to October) seasons respectively, while soil salinity, water logging and acidification affect 3.05 million hectares, 0.7 million hectares and 0.6 million hectare of crop land, respectively in the country. The temperature and rainfall projections for Bangladesh over the next decades show significant temperature increases for both monsoon and winter period. The projections for rainfall indicate more rains during monsoon and lesser during dry periods. Very small changes in the temperature, rainfall or sea level rise can lead to severe consequences for a country.

(b) Increase frequencies of natural disasters: Between 1991 and 2000, 93 major disasters were recorded in Bangladesh, resulting in nearly 200,000 deaths and causing US $5.9 billion in damages with high losses in agriculture and infrastructure. Since then, the country is experiencing recurring floods frequently. The monsoon floods of this year are part of what the World Meteorological Organization sees as a global pattern of record extreme weather conditions. Some major impacts of climate change are presented in Table 1.1.

The risk environment

Identifying the risk environment is the priority factor of any policy making. The building blocks of climate change policies of Bangladesh stand on four pillars: natural infrastructures (e.g., physiology, proximity to the sea, landscape and terrain, watersheds, land type characteristics etc.), socioeconomic infrastructure (e.g., socio-economic profile of major livelihood groups, poverty dimension etc.), physical infrastructure (e.g., roads and highways, healthcare centres, urban centres, village growth centres, industries and factories, school buildings etc.) and institutional infrastructure (e.g., community organizations, Local government Institutes, arrangements of government wings etc.).

According to IPCC in their recently published Fourth Assessment, the following changes have been observed in climate trends, variability and extreme events

- In Bangladesh, average temperature has registered an increasing trend of about $1^{\circ}C$ in May and $0.5^{\circ}C$ in November during the 14 year period from 1985 to 1998.
- The annual mean rainfall exhibits increasing trends in Bangladesh. Decadal rain anomalies are above long term averages since 1960s.
- Serious and recurring floods have taken place during 2002, 2003, and 2004. Cyclones originating from the Bay of Bengal have been noted to decrease since 1970 but the intensity has increased.
- Frequency of monsoon depressions and cyclones formation in Bay of Bengal has increased.
- Water shortages has been attributed to rapid urbanization and industrialization, population growth and inefficient water use, which are aggravated by changing climate and its adverse impacts on demand, supply and water quality.
- Salt water from the Bay of Bengal is reported to have penetrated 100 km or more inland along tributary channels during the dry season.
- The precipitation decline and droughts has resulted in the drying up of wetlands and severe degradation of ecosystems.

Table 1.1: General impacts of climate change in Bangladesh

Effects of Climate change		Impacts	Projection
Direct	More frequent and severe droughts	• decreased water availability • lead directly to conflict over water resources	IPCC -by the year 2050 > 1 billion people in Asia will adversely affect.
		• ruin harvests, leading to malnutrition and migrations	IPCC -by the year 2020 75 - 250 million people exposed to water stress
	Acidification of the oceans	Hinder the formation of shells and skeletons of marine organisms, adversely affecting marine ecosystems.	
	Sea levels rise	• Large scale people migration • Increase frequency of floods, storm surges, salt water intrusion etc. • Contaminate fresh water wells and aquifers.	World Bank - 1 m sea-level rise would affect at least 56 million people.

Effects of Climate change		Impacts	Projection
Direct	More frequent tropical storms and fires started by lightning strikes	• people movements from low-lying areas fleeing the devastation and the loss of farmland • clean water contamination due to saltwater by storm surges.	Large-scale people movements are highly likely to lead directly to conflicts as people try to cross borders and settle on land already claimed by others. Outbreaks of cholera, diarrhoea and other water-borne diseases.
	Loss of biodiversity	• organisms migration • lost of critical 'keystone' species affecting human socio-economic systems • by agriculture and tourism, • loss of irreplaceable natural chemical compounds for pharmaceutical and bioscience research.	
Indirect	'other' economic costs	Impact the insurance industry resulting in higher premiums • affect energy generation companies, finally this will pass costs onto consumers • make insurance unaffordable to those who previously able to afford	
	Higher energy costs lead	• adverse health outcomes since they increase transport, heating and electricity costs for the health sector.	
	Donor fatigue	increased natural disasters and conflicts, spread of tropical diseases etc. will likely increase energy and other economic costs facing donor countries	pressure on donors' aid budgets

This multilevel conception is consistent with the early use of "biological diversity" in Washington. D.C. and international conservation organizations in the late 1960s through 1970's, by Raymond F. Dasmann who apparently coined the term and Thomas E. Lovejoy who later introduced it to the wider conservation and science communities. An explicit definition consistent with this interpretation was first given in a paper by Bruce A. Subsequently, the 1992 United Nations Earth Summit in Rio de Janeiro defined "biological diversity" as "the variability among living organisms from all sources, including, 'inter alia', terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems". This is, in fact, the closest thing to a single legally accepted definition of biodiversity, since it is the definition adopted by the United Nations Convention on Biological Diversity.

Biodiversity found on Earth today is the result of 4 billion years of evolution. The origin of life has not been definitely established by science, however some evidence suggests that life may already have been well-established a few hundred million years after the formation of the Earth. Until approximately 600 million years ago, all life consisted of archaea, bacteria, protozoans and similar single-celled organisms.

The history of biodiversity during the Phanerozoic (the last 540 million years), starts with rapid growth during the Cambrian explosion—a period during which nearly every phylum of multicellular organisms first appeared. Over the next 400 million years or so, global diversity showed little overall trend, but was marked by periodic, massive losses of diversity classified as mass extinction events.

The apparent biodiversity shown in the fossil record suggests that the last few million years include the period of greatest biodiversity in the Earth's history. However, not all scientists support this view, since there is considerable uncertainty as to how strongly the fossil record is biased by the greater availability and preservation of recent geologic sections. Some (Alroy, Marshall et al. 2001) argue that, corrected for sampling artifacts, modern biodiversity is not much different from biodiversity 300 million years ago. Estimates of the present global macroscopic species diversity vary from 2 million to 100 million species, with a best estimate of somewhere near 13–14 million, the vast majority of them arthropods.

Most biologists agree however that the period since the emergence of humans is part of a new mass extinction, the Holocene extinction event, caused primarily by the impact humans are having on the environment. It has been argued that the present rate of extinction is sufficient to eliminate most species on the planet Earth within 100 years.

New species are regularly discovered (on average between 5–10,000 new species each year, most of them insects) and many, though discovered, are not yet classified (estimates are that nearly 90% of all arthropods are not yet classified). Most of the terrestrial diversity is found in tropical forests.

1.8.1 Benefits of biodiversity

Biodiversity also supports a number of natural ecosystem processes and services. Some ecosystem services that benefit society are air quality, climate (both global CO_2 sequestration and local), water purification, disease control, biological pest control, pollination and prevention of erosion. Biodiversity is also believed to create stability in ecosystems, allowing these ecosystems to continue providing services in the face of disturbances.

Non-material benefits that are obtained from ecosystems include spiritual and aesthetic values, knowledge systems and the value of education. Biodiversity is also central to an ecocentric philosophy.

1.8.2 Loss of biodiversity in Bangladesh

The number of species, especially the flora and invertebrates, of Bangladesh are not known for certain. Rahman (2002) reported that Chittagong zone alone possess over 2,259 species of flowering plants. He also stated that there are over 700 species of flowering plants, 500 species of medicinal plants, 300 species of mangrove and mangrove associate plants and 300 species of wetland plants in Bangladesh. The fauna, especially the wildlife includes 125 species of mammals, 750 species of birds, 500 species of fishes, 125 species of reptiles and 9 species of amphibian. Bangladesh has lost about 10% of its mammalian fauna, 3% avifauna and 4% reptile during the last 100 years. IUCN Bangladesh has identified 201 species of wildlife in the country are threatened under different degree of extinction risk (Table 1.2 and Table 1.3). Loss of species is mostly coupled with loss of habitat. For most of these endangered species the forest and wetlands are the last refuge. Forest cover, is also under constant threat. Forests are increasingly being degraded and denuded by encroachment and faulty management practices. Wetlands are in worse condition compared to that of forests. Wetlands are being converted into agricultural land and substantially degraded through the so-called development activities.

Table 1.2: **Status of inland and resident vertebrates of Bangladesh**

Group	Total no. of Living species	Extinct	Threatened				Data deficient (DD)	Not threatened (NO)
			Critically Endangered (CR)	Endangered (EN)	Vulnerable (VU)	Total		
Fishes (freshwater & blackish water)	266	0	12	28	14	54	66	146
Amphibians	22	0	0	3	5	8	7	7
Reptiles	109	1	12	24	22	58	39	12
Birds	388	2	19	18	4	41	158	189
Mammals	110	10	21	13	6	40	53	17
Total	**895**	**13**	**64**	**86**	**51**	**201**	**323**	**371**

Source: (IUCN 2000)

Table 1.3: **Status of marine and migratory vertebrates of Bangladesh**

Group	Total no. of Living species	Extinct	Threatened				Lower Risk (LR)	Data deficient (DD)	Not threatened (NO)
			Critically Endangered (CR)	Endangered (EN)	Vulnerable (VU)	Total			
Fishes (marine)	442	0	0	1	3	4	0	0	438
Reptiles (marine)	17	0	1	4	0	5	0	0	12
Birds (migratory)	240	0	0	2	4	6	6	4	224
Mammals (marine)	3	0	0	2	1	3	0	0	0
Total	**702**	**0**	**1**	**9**	**8**	**18**	**6**	**4**	**674**

Source: (IUCN 2000)

1.9 Ethics

Historically the engineering profession in general and environmental engineering in particular did not consider the ethical implications of solutions to problems. Ethics as a framework for making decisions appeared to be irrelevant to engineering since the engineer generally did precisely what the employer or client required.

Today, however, the engineer is no longer free from concern for ethical questions. Scientists and engineers look at the world objectively with technical tools, but often face questions that demand responses for which technical tools may be insufficient. In some cases all the alternatives to a particular engineering solution include "unethical" elements. Engineers engaged in pollution control, or in any activity that impinges on the natural environment, interface with environmental ethics. An environmental ethic concerns itself with the attitude of people toward other living things and toward the natural environment, as well as with their attitudes toward each other. The search for an environmental ethic raises the question of the origin of our attitude toward the environment.

It is worth noting that the practice of settled agriculture has changed the face of the earth more than any other human activity; yet the Phaestos Disk—the earliest Minoan use of pictographs—elevates to heroism the adventurer who tries to turn North Africans from hunting and gathering to settled agriculture. The tradition of private ownership of land and resources, which developed hand-in-hand with settled agriculture, and the more recent tradition of the planned economies that land and resources are primarily instruments of national policy have both encouraged the exploitation of these resources. Early European settlers arriving in the New World from countries where all land was owned by royalty or wealthy aristocrats considered it their right to own and exploit land. An analogous situation occurred with the Soviet development of Siberia and the eastern lands of the former Soviet Union (now the Russian Federation): land once under private ownership now belonged to the state. Indeed, in both America and Russia, natural resources appeared to be so plentiful that a "myth of superabundance" grew in which the likelihood of running out of any natural resource, including oil, was considered remote. These traditions are contrary to the view that land and natural resources are public trusts for which people serve the role of stewards.

Nomadic people and hunter-gatherers practiced no greater stewardship than the cultures based on settled agriculture. In the post-industrial revolution world, the less industrialized nations did less environmental damage than industrialized nations only because they could not extract resources as quickly or efficiently. The Navajo sheepherders of the American southwest allowed overgrazing and consequent erosion and soil loss to the same extent as the Basque sheepherders of southern Europe. Communal ownership of land did not guarantee ecological preservation.

Both animistic religion and early improvements in agricultural practices (e.g., terracing, allowing fallow land) acted to preserve resources, particularly agricultural resources. Arguments for public trust and stewardship were raised during the nineteenth century, in the midst of the ongoing environmental devastation that followed the industrial revolution. Henry David Thoreau, Ralph Waldo Emerson, and later John Muir, Gifford Pinchot, and President Theodore Roosevelt all contributed to the growth of environmental awareness and concern. One of the first explicit statements of the need for an environmental ethic was penned. Since then, many have contributed thoughtful and well-reasoned arguments toward the development of a comprehensive and useful ethic for judging questions of conscience and environmental value.

Since the first Earth Day in 1970 environmental and ecological awareness has been incorporated into public attitudes and is now an integral part of engineering processes and designs. Environmental awareness and concern became an essentially permanent part of the US public discourse with the passage of the National Environmental Policy Act of 1970. Today, every news magazine, daily newspaper, and radio and TV station in the United States has staffs that cover the environment and publish regular environmental features. Candidates for national, state, and local elective office run on environmental platforms. Since passage of the National Environmental Policy Act, no federal public works project is undertaken without a thorough assessment of its environmental impact and an exploration of alternatives. Many state and local governments have adopted such requirements as well, so that virtually all public works projects include such assessments. Engineers are called on both for project engineering and for assessing the environmental impact of that engineering. The questions that engineers are called upon to answer have increased in difficulty and complexity with the development of a national environmental ethic.

The growing national environmental ethic, coupled (unfortunately) with a general lack of scientific understanding, is at the root of public response to reports of "eco-disasters" like major oil spills or releases of toxic or radioactive material. As a result, this public response includes a certain amount of unproductive hand-wringing, occasional hysteria, and laying of blame for the particular disaster. The environmental engineer is often called on in such situations to design solutions and to prevent future similar disasters, and is able to respond constructively.

In recent years, and particularly after the accident at the Three Mile Island nuclear plant in 1979, the release of methyl isocyanate at the chemical plant in

Bhopal, India, in 1984, and the disastrous nuclear criticality and fire at the Chernobyl nuclear power plant in 1986, general appreciation of the threats to people and ecosystems posed by toxic or polluting substances has increased markedly. In 1982 the U.S. Environmental Protection Agency (EPA) began to develop a system of "risk-based" standards for carcinogenic substances. The rationale for risk-based standards is the theory, on which regulation is based, that there is no threshold for carcinogenesis. The U.S. Nuclear Regulatory Commission is also considering risk-based standards. As a result of the consequent increase of public awareness of risk, some members of the public appear to be unwilling to accept any risk in their immediate environment to which they are exposed involuntarily. It has become increasingly difficult to find locations for facilities that can be suspected of producing any toxic, hazardous, or polluting effluent: municipal landfills, radioactive waste sites, sewage treatment plants, or incinerators. Aesthetically unsuitable developments, and even prisons, mental hospitals, or military installations, whose lack of desirability is social rather than environmental, are also difficult to site. Popper (1985) refers to such unwanted facilities as locally undesirable land uses, or LULUs.

Local opposition to LULUs is generally focused on the site of the facility and in particular on the proximity of the site to the residences of the opponents, and can often be characterized by the phrase "not in my back yard." Local opponents are often referred to by the acronym for this phrase, NIMBI The NIMBY phenomenon has also been used for political advantage, resulting in unsound environmental decisions. The environmental engineer is cautioned to identify the fine line between real concern about environmental degradation and an almost automatic "not in my back yard" reaction. He or she recognizes, as many people do not, that virtually all human activity entails some environmental alteration and some risk, and that a risk-free environment is impossible to achieve. The balance between risk and benefit to various segments of the population often involves questions of environmental ethics.

Is it ethical to oppose a particular location of an undesirable facility because of its proximity to ecologically or politically sensitive areas, rather than working to mitigate the undesirable features of the facility? Moreover, is it ethical to locate such a facility where there is less local opposition, perhaps because employment is needed, instead of in the environment where it will do the least damage? The enactment of pollution control legislation in the United States has had a sort of NIMBY by-product: the sitting of U.S.-owned plants with hazardous or toxic effluents, like oil desulphurization and copper smelting, in countries that have little or no pollution control legislation. The ethics of such "pollution export" deserve closer examination than they have had.

1.9.1 Inculcation of environmental ethics in Bangladesh

Ethics are embedded in the value system of a society. A baby after being born learns how it is supposed to behave, what is right, what is wrong, etc. Thus the way in which environmental ethics is inculcated within the individual is the same way as the individual is socialized. The primary agencies of socialization are the family, peer groups, education, religion, and nowadays the mass media is playing a significant role in socializing. Now we will discuss these in detail.

The family: Usually, a baby is born to a family. Its first socialisation takes place within this primary group. It learns to do things, first of all from its mother, and also from its father, siblings and other members of the family. When a baby is given the ideas of "right" and "wrong", it is important that a baby learns the ways he/she should interact with the environment. In this way it is possible to inculcate environmental ethics that will make an individual behave and act in environment friendly ways, from the very beginning of his/her life. For example, when a child notices that its parents and elder siblings care about trees and plants, avoid the wastage of water, follow the habit of recycling, etc, the child is very likely to acquire these qualities within himself/herself. Parents can teach their children how important the environment is for all of us, and the ways in which we can protect it.

Peer group: Beyond the realm of the family, an individual learns from different situations that he/she encounters within his/her peer group. Approval of peer group functions is a significant motivating factor in one's social behaviour (Bond 1952). If any one member of a peer group acts in an environmental friendly manner, others are also inspired. The sharing of information occurs among peer group members in an informal fashion, which has a long lasting effect on the formation of environmental friendly habits. Thus if a person is conscious about the environment and has a sufficient influence, all the other members are also likely to follow him/her.

Religion: Religion is a social institution that forms the core of the value system of an individual/ society. More than 85% of the people of Bangladesh are followers of Islam. It is said in Islam that the environment is one of God's creations, and as his representatives, humans have a duty to preserve it. Man must be kind towards all that has been created by God on earth; the plantation of trees is encouraged and the destruction of fruit-giving trees and crops is forbidden, even during a time of war. Religion forbids waste, calling someone who wastes "a brother of Satan". Cleanliness is a significant part of the Islamic faith. The relationship between all the creations of God must be based on justice and equity. Justice is to be maintained for the people who are alive today and for those who will come to live on earth in the future and for this reason the environment must be protected (Popper 1985).

The Hindus are second largest religious group in Bangladesh. According to Hindu scriptures, man receives a lot from nature and has a responsibility to pay back nature by protecting the environment(Oâ€™Keefe, Rose et al. 2008). Often because of their ignorance, people are not aware of these sayings of religion that emphasize protection of the environment so much. As the people of Bangladesh are known to be peace loving, pious people, they can easily be motivated to behave in environmental friendly ways through religious leaders. The ministry of environment in Bangladesh must make use of such an effective agency to convince people regarding the ethics they must up hold to save their mother Earth. People can also learn about these words of religion from their families and friends.

Education: Education is another social institution, which implants ideas of morality into an individual. Aspects of moral judgments, which may not be learned within the family because of lack of knowledge of its members, can be learned through education. The realm of education is very vast — a person can learn from schools/colleges/universities, as well as from books, mass education programmes, special education programmes etc. A student takes his/her teacher as a role model, and often follows his/her teachers' instructions more keenly than instructions given to them by their parents. The curricula can be set in such a manner so that students may grow to be environmental friendly people. Side-by-side the real situation in society should be such that people can apply what they learn as morally right and wrong regarding their interaction with the environment. For example, people may learn that they should not use fuel wood for cooking; but if the actual situation is such that there is no alternative fuel made available for them to use, this learning is not going to be applied.

The mass media: In today's world, the mass media is playing a greater role in informing mass communities of matters of which they were not aware before. The mass media has been very successful in Bangladesh in motivating people to immunize their children, and to plant trees and take care of them. Environmental issues can be introduced to the people in a manner, which is very much appealing to them. Big celebrities can come forward in getting messages across to the public, which would tell them what they should do and what they should not do. We are mainly concerned with the application of ethics for sustainable development in Bangladesh in this paper. However, it is not only the ethical values and action of people in Bangladesh that is responsible for the environmental degradation that takes place in the country. For example, the people of Bangladesh are the least responsible for the emission of CFCs that causes the green house effect. However, this is likely to affect Bangladesh severely within less than half a century through a sea level rise. Therefore, it is necessary to think holistically and to see ourselves "as part of a single moral community that is global in scope and extended in time". We must also be "mindful" in all our acts. The things we are doing today, thinking as "innocent acts" are not innocent when done in concert (J.K and Editor-in-Chief:Â Â Kris 2008). We may think driving a car is an innocent act, but when everyone in a country drives a car, collectively, this helps to deplete the ozone layer significantly. There are countries, which are thinking of imposing an emission tax to discourage the emission of carbon dioxide gases. However we argue that imposing these taxes is not going to help in the long run, unless people are ethically convinced.

The onus is on the general public to take the responsibility to save our planet for future generations. We must share resources in such a way that future generations will be able to continue to develop it is possible for them to act in a holistically, environmentally friendly manner. It has been observed in a study by Mara and Feachem (2003) that environmental risks, which are caused by the cumulative actions of many people, "carry the highest potential for acceptance of personal responsibility" by individuals. In order to make people conscious and active regarding their responsibilities towards the environment, this type of risk should be highlighted.

1.10 Environmental Engineering as a Profession

The general mission of colleges and universities is to allow students to mature intellectually and socially and to prepare for careers that are rewarding. The chosen vocation is ideally an avocation as well. It should be a job that is enjoyable and one approached with enthusiasm even after experiencing many of the ever-present bumps in the road. Designing a water treatment facility to provide clean drinking water to a community can serve society and become a personally satisfying undertaking to the environmental engineer. Environmental engineers now are employed in virtually all heavy industries and utility companies in the United States, in any aspect of public works construction and management, by the EPA and other federal agencies, and by the consulting firms used by these agencies. In addition, every state and most local governments have agencies dealing with air quality, water quality and water resource management, soil quality, forest and natural resource management, and agricultural management that employ environmental engineers. Pollution control engineering has also become an exceedingly profitable venture.

Environmental engineering has a proud history and a bright future. It is a career that may be challenging, enjoyable, personally satisfying, and monetarily rewarding. Environmental engineers are committed to high standards of interpersonal and environmental ethics. They try to be part of the solution while recognizing that all people including themselves are part of the problem.

1.11 Water Supply and Sanitation

Water intake is essential for human survival. An adult male generally need a daily intake of 2 to 2.5 litres water on average to guarantee the equilibrium of his physiological functions. The important pathway for the transmission of many of the water-related diseases is through the contamination of drinking water sources in many situations by classical water-related pathogens, such as typhoid and cholera, however, newly-recognized pathogens and new strains of established pathogens are being discovered that present significant additional challenges to both the water supply and sanitation (WSS), and public health sectors. Between 1972 and 1999, 35 new agents of disease were discovered and many more have re-emerged after long periods of inactivity, or are expanding into areas where they have not previously been reported. It is evident from (WHO 1998) that environmental sanitation can reduce the incidence of infectious diseases by 20% to 80% by inhibiting diseases generation and interrupting disease transmission. Hence safe, adequate and accessible supply of water together with sanitation is basic needs and most effective means to improve public health and saves lives. But the concept of safe, this should be free from pathogenic microbes and toxic chemical, water is becoming more and more difficult to establish. A study on chemical contamination of the water published by the National Academy of Science in the United States in 1980 alert that only 10% in mass of the total amount of pollutant found in water are known and only some of them have safe doses and consequences completely understood. It is apparent that the risk of toxic chemicals and metals in water still seem insignificant by comparison with the health hazards of viral and bacterial contamination, but the increasing magnitude of chemical pollution is leading towards an even more critical problem in the future, being one involving more complicated technical matters.

Due to tremendous growth of the human population during the last century, the provision of adequate, safe water as well as extension of sanitation systems has become a challenging task particularly in developing countries. Again the population growth alone does not reflect the real picture of demand of human being which is much more than that population growth rate. Although the world's population growth at the beginning of 1970s was about 2 percent per annum, but the annual increase of relevant activities to support that augmented population were much higher (Table 1.4). Human activities tend to produce a large number of products, both as waste and useful product that eventually end up as waste. Before the development of consumer-based societies and industrialization, disposal of waste did not create significant problems due to existence of vast tracts of disposable lands, vegetation and natural water bodies; they were able to assimilate them very efficiently. The growing consumption of products in densely populated areas has resulted in a corresponding rise in the production of waste. This has led the abuse of previous natural dilution strategy of waste management and has posed as a tremendous threat to natural (soil, water and air) environment, and resulting overall environmental degradation and health hazards. With the rapid growth of urbanization the slum population in the major cities of developing countries is increasing at an alarming rate where the Water Supply and Sanitation (WSS) coverage is extremely deficient. People living in these urban poor areas contribute significantly in the country's economy but it is ironic that they are often deprived of the basic need which is supposed to be provided by the utility service providers. In Bangladesh the proportion of the rural population without safe drinking water increased to 21.4 per cent in 2006, from 6.9 in 1991 (Rahman et al. 2008). One of the prime reasons for this fact was

Table 1.4: World average annual rate of increase of selected aspects of human activities (%)

Agricultural production	3
Industrial base on farm products	6
Mineral production including fuel	5
Industrial base on mineral products	9
Construction and transportation	6
Commerce	5

detection of arsenic contamination in groundwater. Around 20% of the population in Bangladesh does not have access to water free from arsenic contamination and most of them have returned to other surface water sources which are not free from microbial contamination. Although the developing countries attained remarkable progress in terms of sanitation coverage over the last two decades, however, still a large number of populations do not have the access to safe excreta disposal system which is identified as potential hazard to human health and surrounding environment. From 1990 to 1994, approximately 800 people gained access to safe water but due to population growth the number of people un-served decreased only from 1,600 million to 1,100 million and most of them lives mostly in developing countries. During the same period the number of people without sanitation increased by 300 million. About 3.57 million deaths a year worldwide are attributed to unsafe water, sanitation and hygiene, out of which about 1.5 million through infectious diarrhoea. Nine out of ten such deaths are in children, and virtually all the deaths are in developing countries. Although the occurrence of diarrhoeal and other faecal-oral diseases follow complex web of pathways as shown in Figure 1.8, which often makes it very difficult to reduce the incidence of diarrhoea through

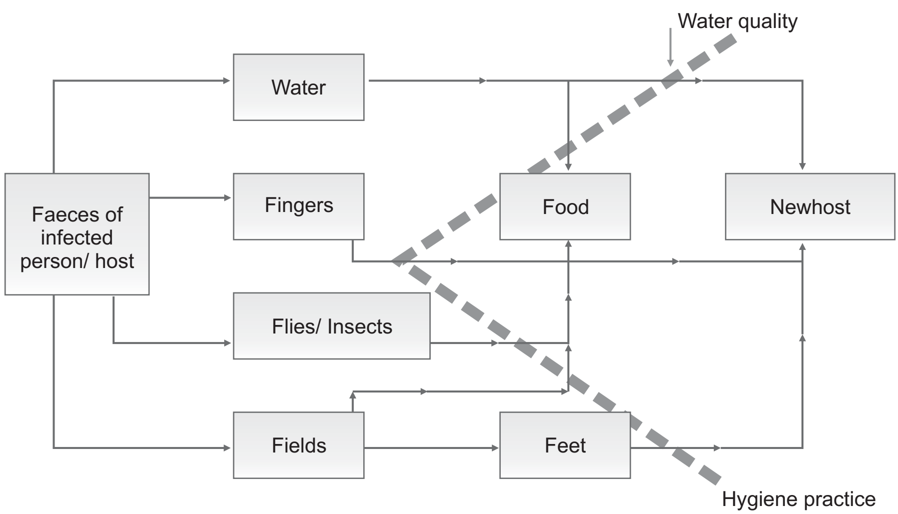


Figure 1.8: Transmission of disease from faeces

water, sanitation interventions, but interventions to improve water, sanitation, and hygiene practices have been shown to reduce sickness from diarrhoea by between a quarter and a third. Globally, 66% of the disease is attributable to unsafe water, inadequate sanitation or insufficient hygiene. A study conducted by the Pacific Institute estimated that if no action is taken to address the lack of water, sanitation, and hygiene, as many as 135 million preventable death will occur by 2020. Hence presently millions suffer from infectious diseases and majority of them referred to water, sanitation, and hygiene related. These diseases are generally caused by pathogenic microbes, toxic chemicals and water-habitat vectors, which are summarized as 5 categories in Table 1.5.

Table 1.5: Categories of water, sanitation and hygiene related diseases

Category	Description	Examples	Annual deaths (Global)
Water borne diseases	Ingestion of water contaminated by human or animal excreta or urine.	Diarrhoeal diseases: Cholera E.Coli Diarrhoeas Viral Diarrhoeas Other Diarrhoeas Dysenteries: Amoebic Dysentery Bacillary Dysentery	1.5 million (diarrhoea) 12 thousand (Intestinal nematode infections)
Water Hygiene Diseases	Use of contaminated water for hygiene practice	Eye related diseases: Trachoma Conjunctivitis Infectious skin diseases: Scabies	
Vector borne diseases	Insect/micro organisms Use water for their breeding space	Malaria Dengue Filariasis	526 thousand (Malaria) 18 thousand (Dengue)
Water based helminthiases	Transmission through pathogens associated with excreta or vectors breeding in excreta	Schistosomiasis Clonorchiasis	15 thousand (Schistosomiasis)
Water borne chemical diseases	Occurrence of diseases due to the intake of chemically contaminated water	Skin manifestations: Melanosis Keratosis Others: Respiratory Problem Cardiovascular Diseases Cancer	

The World Summit on Sustainable Development (WSSD) held in 2002 recognised that water and sanitation is inextricably linked to the eradication of poverty and attainment of the sustainable development. In fact, water was identified by the then UN Secretary General as one of the five specific "WEHAB" areas (water, energy, health, agriculture and biodiversity) in which concrete results are both essential and achievable. The WSSD reiterated the Millennium Development Goal (MDG) of halving by 2015 the proportion of people who are unable to reach or to afford safe drinking water and to set a new target on halving the proportion of people who do not have sustainable access to basic sanitation. Thus the Goal 7, Target 10 of MDG is to half the proportion of people without the sustainable access to safe drinking water and basic sanitation. Existing WSS facilities in the developing countries indicate that achieving this target by 2015 encompasses significant challenges.

1.11.1 Water supply

It is apparent from the Human Development Report 2006 that the water crisis is holding back human progress, consigning large segments of population into poverty, vulnerability and insecurity. Water is required for both the life and the livelihoods. It is essential to the well-being of humankind, to the economic development, and more importantly for the healthy functioning of the world's ecosystem. Life expectancy of a country significantly increases when there is safe water with adequate supply. Delivering clean water, therefore, is one of the most basic foundations for human progress. The developing countries, however, are facing enormous challenges to ensure adequate coverage of safe drinking water specifically for the poor community. Some of the major issues related to water supply in the context of developing countries include: increased water demand and reduced water availability; over exploitation of groundwater; degraded water quality due to physical, chemical and bacteriological contamination; damage to infrastructure due to erratic behaviour of climate including natural disasters; addressing the challenges of poor urban areas; and, lack of institutional coordination. In addition to inadequate coverage with safe drinking water supply, the health risk also aggravates due to the fact that around 4.0 billion people do not treat their water to any degree.

By 2006 around 884 million population reliant on unimproved drinking water sources and rest 87 percent (Figure 1.9) of the world's population uses drinking water from improved sources. About half of the population who do not have access to an improved drinking water source live in Asia (Figure 1.10) among

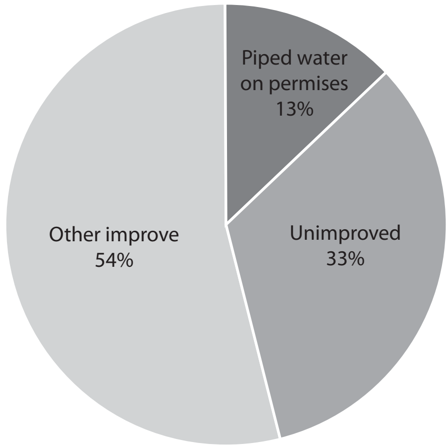


Figure 1.9: **Proportion of the world's population using improved or an unimproved drinking water source in 2006**

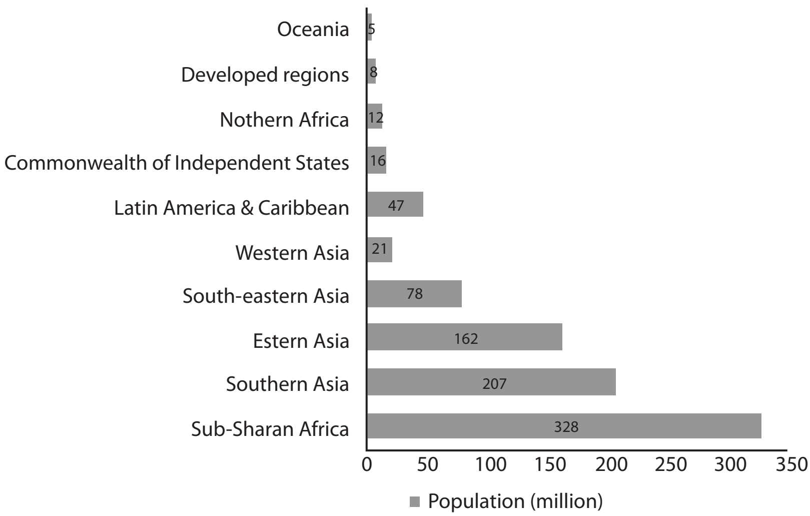


Figure 1.10: **Population using an unimproved drinking water source, by region in 2006**

where South Asia holds the largest share. In south-east Asia apart from Afghanistan, Bangladesh has the lowest coverage (Figure 1.11) with improved sources drinking water supply. Bangladesh along with some other countries have achieved significant progress regarding MDG target but still not sufficient; that is coverage in 2006 was 5 percent to 10 percent below the rate it needed to be for

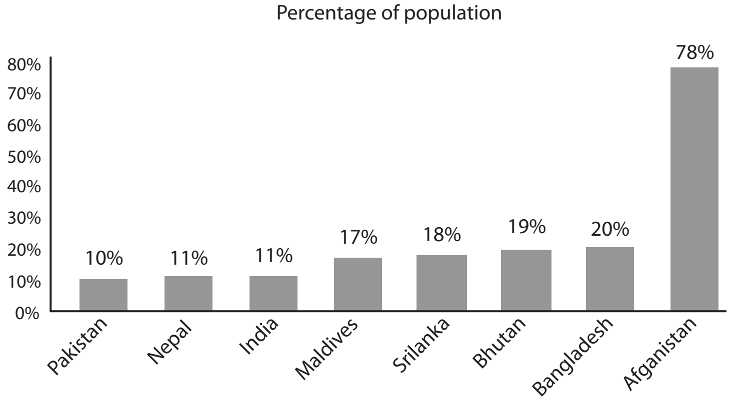


Figure 1.11: **Percentage of population using an unimproved drinking water source in south-east Asian countries in 2006**

the country to reach the MDG target. More than 31 million (20%) people in Bangladesh collect drinking water from unimproved sources which are not safe. In rural area 22% and in urban area 15% of the population does not have access to improved sources for drinking water (Table 1.6).

Table 1.6: **Drinking water supply coverage of Bangladesh**

	Improved sources (%)		
Area	**Piped into dwelling, yard or plot**	**Other improved**	**Unimproved sources (%)**
Urban	20	65	15
Rural	-	78	22
Total	5	75	20

1.11.2 Sanitation

Compared to drinking water supply coverage, the global scenario of sanitation coverage is not satisfactory. The sanitation coverage till 2006 is lagging significantly behind the MDG target and at the present rate of progress the world will be able to achieve only 67% (against the target of 67%) of sanitation coverage by 2015. More than 2.5 billion people, representing almost half of the world population, do not have access to adequate or improved sanitation facilities (WHO 2008). Coverage with improved sanitation facilities is lowest in Sub-

Saharan Africa and Southern Asia which is 31% and 33% respectively (Figure 1.12). Open defecation is still widely practised in Southern Asia (48% of the population). Again, not using of improved means of excreta disposal by 38% of the world's population is a major area of concern (Figure 1.13). Disparities are also significant in rural and urban coverage of sanitation.

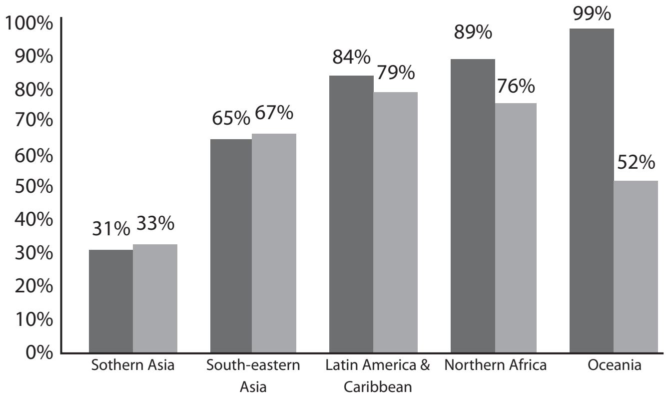


Figure 1.12: **Coverage with improved sanitation facilities, by region in 2006**

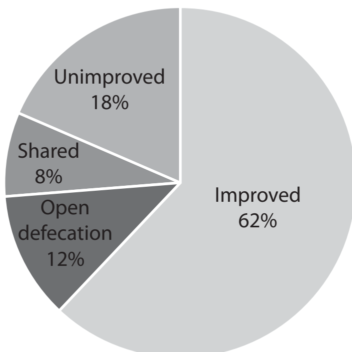


Figure 1.13: **Sanitation practice scenario by proportion of the world's population, 2006**

In South Asia open defecation practice by the population of the country is still more than 50% in both India and Nepal (Figure 1.14). About 668, 50 and 14 million people respectively in India, Pakistan and Nepal practice open defecation. In Bangladesh, about 18 million (11%) people practice open defecation, 37% people use unimproved means and only 36% people use

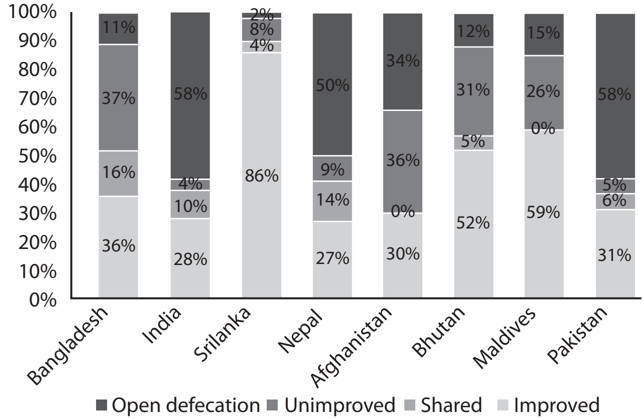


Figure 1.14: **Sanitation coverage of South Asia in 2006**

improved means for excreta disposal. Comparison of sanitation progress, which is basically the hygienic latrine coverage, reported by Sanitation Secretariat of Department of Public Health Engineering (DPHE) and other organizations in Bangladesh is shown in Table 1.7. Ambiguity was found in coverage data reported by different organizations. The ninth round of Multiple Indicator Cluster Survey (MICS) was implemented in Bangladesh in 2006 which shows a much lower value of 39.2% coverage compared with that of SS of DPHE data, which shows 77.8% coverage (Table 1.7). NGO Forum for Drinking Water Supply and Sanitation (a national NGO), has been implementing a project in 350 Unions in 104 Upazilas of 45 Districts in Bangladesh and conducted a baseline survey on sanitation in these areas (Rahman, Rahman et al. 2008). Similarly, Dhaka Ahsania Mission (a NGO) is implementing the Dishari Project and monitoring the sanitation coverage in the project area. BRAC (a NGO) is also implementing WASH programme in 150 Upazilas where baseline survey was conducted before implementing the programme. Theses baseline sanitation status shows a lot of variations than the sanitation coverage reported by SS of DPHE (Table 1.7). But the parameters of sanitation coverage survey were different in different surveys, which created this 'ambiguity'. Apart from that followings are the main reasons for ambiguity in different sanitation coverage data in Bangladesh:

Present monitoring data of Sanitation secretariat does not distinguish between latrines "without water seal" or "broken water seal" with hygienic and unhygienic

Figure 1.7: Comparison of sanitation progress reported by Sanitation Secretariat (SS) and other organizations

Organization	Reportin g period	% of HH using hygienic latrine	% of HH using hygienic latrine + latrine without water seal	% of HH using unhygienic latrine	% of HH practicing open defecation
A	B	C	D	E	F
NGO Forum	2006	33.2	69.7	24.8	5.5
SS	2006	81.6*			
Unicef	2006	39.2	73.1	19.4	7.5
SS	2006	77.8*	-	-	-
BRAC	2007	31.1	-	-	-
SS	2007	85.6*	-	-	-
Dishari	2007	60.6	-	-	-
SS	2007	84.2*	-	-	-

* sanitation coverage reported by Sanitation secretariat of the areas surveyed by other institutions

latrines; and, the increase in household numbers from year 2003 has not been considered in the progress estimation by Sanitation secretariat.

Table 1.7 shows that a large number of population (around 27 - 30%) in Bangladesh have an unsanitary system consisting of unhygienic latrine and open defecation directly into the living environment, Even the households in rural and slum areas, where sanitary facilities are available, children rarely use them due to lack of health education. Where sanitary facilities are not available, the septic tank effluent, bucket latrine wastes, waste water form residential, commercial and industrial establishments are being discharged into storm drains or open water bodies without regard to effluent quality or their detrimental effects on water courses and living environment (Rahman and Bache 1993). Rahman and Bache (1993) reported that both wastewater from drainage system of slum areas and surface wash from slum areas are extremely polluted (BOD_5 = 400-1,700 mg/l, Suspended Solid = 500-3,000 mg/l). The only sewerage system of DWASA (10% coverage) is currently operating at its maximum capacity but this sewage treatment plant of DWASA is not adequate for the treatment of sewage to a satisfactory level. However, the overall sanitation situation in Bangladesh is improving and it is apparent from SS of DPHE that about 14.5% households

(HH) in city corporations, 10.87% HH in municipalities and 12.92% HH in rural areas do not have access to hygienic latrine in June 2008 (Table 1.8).

Table 1.8: **Status of sanitary latrine in Bangladesh**

Area	According to Baseline Survey, October 2003			Coverage up to June 2008
	Total number of families	No. of families not using sanitary latrines	% of families not using sanitary latrines	% of families not using sanitary latrines
City Corporations	1,216,424	365,897	30.1	14.5
Municipalities	1,851,337	868,312	46.9	10.9
Rural	18,326,332	13,053,743	71.2	12.9
Country Total:	21,394,093	14,287,952	66.8	11.8

The management of solid waste is a major concerning issue in urban centres of developing countries in general and Bangladesh in particular. Approximately 16,380 tons/day of waste has been generated in the urban areas of Bangladesh in the year 2004. The quantity of solid waste in Bangladesh is low compared with that of developed countries. This is mainly because of extensive recycling operation that is carried out by scavengers at various stages of solid waste collection. In spite of extensive unplanned recycling mostly by scavengers for their own economic interest, the most of the cities/municipalities can not collect and dispose of 40-60% of their total generated solid waste. There is very low coverage of solid waste collection services particularly for the poor who receive minimal services, and as a result they often dispose of their solid waste into low-lying areas and storm drains. It is apparent from Table 1.9 that the major components of solid waste collected from bins of residential and commercial areas in Bangladesh include organic waste. These wastes often degrade and serve as breeding ground of diseases vectors. There is overflow of leachate with high organic loads (BOD_5 = 5,000 - 15,000 mg/l and SS = 3,000 - 14,000 mg/l) during rainy season which ultimately contaminates ground and surface water resources (Rahman 2002). Thus the present status of sanitation practice for wastes management requires special attention to improve the situation.

Due to very high demand of health care services in Bangladesh, the total quantity of Health Care Waste (HCW) from different Health Care Establishments

Table 1.9: Composition of solid waste in Dhaka city

Constituent	% by weight	
	Residential area	Commercial area
Food waste	75-85	72-83
Paper	4-6	5-7
Plastic, rubber	1-2	1-2
Textiles	1-2	1-2
Glass, metals, ceramic, grass, construction materials, etc.	5-7	8-10

(HCEs), which appeared to be reformed as a profitable business sector, is growing at a very fast rate. Like other developing countries, majority of hazardous HCW and toxic industrial wastes in Bangladesh find their ways into domestic solid waste streams. The primary concerns related to these hazardous wastes are the risk of transmission of diseases. Until recently, the management of HCW has received little attention despite their potential environmental hazards and public health risks. This needs attention of the government, HCE and other related authority before the risks associated with the wastes become more dangerous and wastes becomes unmanageable. Almost all of HCEs in Bangladesh do not have waste management policies or plans, documented waste handling procedures, pre-treatment options before sending the hazardous waste for disposal into disposal sites or the nearby municipal bins, manpower for infection control or operational infection control committee to monitor or prevent infection even in their premises. However, a few alterations in material procurement, staff education particularly for the workers involved in collection, segregation and in-house management in HCEs can minimize the quantity of hazardous portion in many situations.

Bangladesh has made a significant stride towards industrialization. There are more than 30,000 small and large industrial units in Bangladesh, of which about 24,000 are small or cottage industries (Rahman 2002). The rest may be considered as medium to large-scale enterprises. The major polluting industries are tannery, distillery, paper and pulp, textile, fertilizer, sugar, steel, oil refining, chemical, pharmaceutical, and other small scale agro-based and agro-allied industries. A large number of these industries are located in densely populated urban centers along the banks of the rivers. Huge amount of water is required for different industrial processes, but a small portion of that water is incorporated in their product and lost by evaporation, the rest, in most cases (Table 1.10), find their way into open water sources as wastewater without any form of treatment. Typical effluent qualities of selected industries are presented in Table 1.11.

Table 1.10: Types of pollutants and applied pollution measure in major polluting industries in Bangladesh

Industries	Type of Emission	Type of Pollutants	Remark
Leather tanneries	Wastewater, gaseous emission and solid waste	Dissolved lime, hydrogensulphide acids, chromium, dyes, oils, SS, organic matter, H_2S, SPM, Lime and chromium sludge, fleshing, shavings, trimmings	Old tanneries do not have treatment plants only the Bata Tannery at Noyarhat and the New Dhaka Leather Complex have a modern wastewater treatment plant
Textile Industries (Dyeing & Printing)	Wastewater, gaseous emission and solid waste	Alkali, Cl, dyes, organic matter, detergents, N, P, SS, SPM, yarn, cloth, packing materials, ink waste	Few apply lagooning for storage and water hyacinths for wastewater treatment waste water are discharged
Paper and pulp Industry	Wastewater, gaseous emission and solid waste	Organic matter, odorous compounds, wastewater, sludge, ash, bark wood waste, paper trash	without any form of treatment
Sugar Industry	Wastewater, gaseous emission and solid waste	SS, organic matter SPM, bagasse	Only lagooning for storage in almost all sugar mills & distilleries
Fertilizer Industries	Wastewater, gaseous emission and solid waste	H_2SO_4, H_3PO_4, HF, fluorides, phosphates, NH_3, NH_4-salts, Amines, CH_3-OH, H_2S, SPM, fluorides, NH_3, gypsum, arsenic sludge	In Ghorashal only lagooning. In CFL & JFL modern waste treatment facilities have been installed with ammonia striping
Electroplating industries	Wastewater, gaseous emission and solid waste	Oil, grease, chloride hydrocarbons, acids, alkalis, H_2S, CN, Cr, Cd, Ni, Cu, Zn, Ag, acids, mists, vapors metal and lime sludge	Occasionally alkali treatment for metal recovery and neutralization. Gaseous emissions are not controlled

Industries	Type of Emission	Type of Pollutants	Remark
Caustic Chlorine Plants	Wastewater, gaseous emission and solid waste	Hg, Chlorides, Cl, NOx, Hg, brine mud	Sedimentation
H_2SO_4 Plant	Wastewater, gaseous emission and solid waste	Acids SO_2	Neutralization & wet scrubbing
Paint Industries	Wastewater, gaseous emission and solid waste	Cr, pb, Cu, Cd, organic solvents packing materials (rejected paint cans)	No treatment
Pesticides and insecticides industries	Wastewater, gaseous emission and solid waste	Acids, organic solvents, CN, Cl, phenolic compounds, Pb, Cu, As, Hg, organic solvents acids vapors package materials, filter dust, sludge	Some plants apply neutralization, solid waste incineration and bag filtration

Source: (Rahman 2002).

Table 1.11: **Typical effluent quality of selected industries**

Industries	pH	Maximum BOD_5, (mg/l)	Maximum suspended solids (SS), (mg/l)
Tanneries	3.5 - 11.8	38,500	33,500
Pulp and paper	6.3 - 11.0	1,300	3,500
Textiles	3.9 -11.8	8,100	15,500
Vegetable	7.0 - 8.0	120	900
Sugar	4.6 - 7.1	2,000	3,000

Bangladesh is predominantly is an agricultural country and thus a large number of chemicals are used as fertilizers and pesticides/insecticides for the production of different crops. Urea, Triple Super Phosphate and Murate of Potash are the major chemical fertilizers used in Bangladesh as a source of nitrogen, phosphorous and potassium. In 1999-2000, the total consumption of urea, triple supper-phosphate and single supper-phosphate in Bangladesh was around 1.9×10^6, 2.3×10^5 and 2.0×10^5 tons respectively. All these fertilizers applied are not utilized by the crops and therefore, a large amount of these chemicals, heavy metals along with pathogens are being drained out or being carried out by eroded soils into the natural water bodies. Nitrogen and phosphorous contribution to natural watercourses in Bangladesh from agricultural land drainage vary from 1.5 kg to 11 kg of nitrogen and up to 3 kg of phosphorous per acre per year. Phosphorus, for example, can be approximately 10 times higher in surface runoff than in groundwater. These nutrients enhance eutrophication and algal growth and lead to deterioration of overall water quality. Pest control is also an integral part of modern agriculture but unfortunately it has the most adverse impact on the environment. Some of these synthetic organic insecticides are rapidly degradable with a life time of 1 to 10 weeks, but others have a half life of 2 to 4 year and some heavy metals have a half life of about 10 to 30 years. Agricultural runoff after spray application may increase the concentration of pesticides in water sources to a level, lethal to all fish species.

Box 1.2

Nabolok WatSan Initiatives in Khulna City

Nabolok started its Advancing Sustainable Environmental Health (ASEH project implementation in the Munshi rice Mill area close to the Rupsha Primary and Secondary School in ward No. 31 of Khulna City of Bangladesh during May 2006. The WatSan situation of the area was unbearable before commencement of the project. An unhealthy two chamber latrine with a tank without cover was used by 158 individuals belonging to 37 households. Women could use the latrine only in the pre-dawn darkness and after sunset. Children were the worst sufferers. Many of them had to visit the latrine several times a day due to various bowel troubles. But due to the crowding of adults, the children used to relieve themselves anywhere.

After implementation of the project, most benefits are being enjoyed by women and children. Most of the family members are now having less frequent bowel troubles and hence medical expenses of 200-300 taka per month are being saved. Moreover, the children can attend schools regularly and the adults are having more working days.

Recent assessments detail alarming trends in pollution of the worlds freshwater and emphasize the destructive effects of eutrophication caused by increased anthropogenic nitrogen and phosphorus loading and increasing pollution by pesticides, heavy metals, and bacteria, among other pollutants. Many of this second group of agents are persistent and can have human health impacts even in very low concentrations and over long periods of time.

1.11.3 Health impact

Unimproved water sanitation status can cause significant affect on human health as revealed by the project carried out by Nabolok, a NGO (Box 1.2). Diseases contributing to the water, sanitation and hygiene related disease burden in Disability Adjusted Life Years (DALYs) are shown in Figure 1.15. More than 1.5 million people die every year because of diarrhoea, 90% of which are children (0-14 years) and 99% of which occur in developing countries. In terms of DALYs diarrhoea and its variants are accountable for an annual loss of 52.46 million. Around 88% cases of diarrhoea worldwide are attributable to unsafe water, inadequate sanitation or insufficient hygiene.

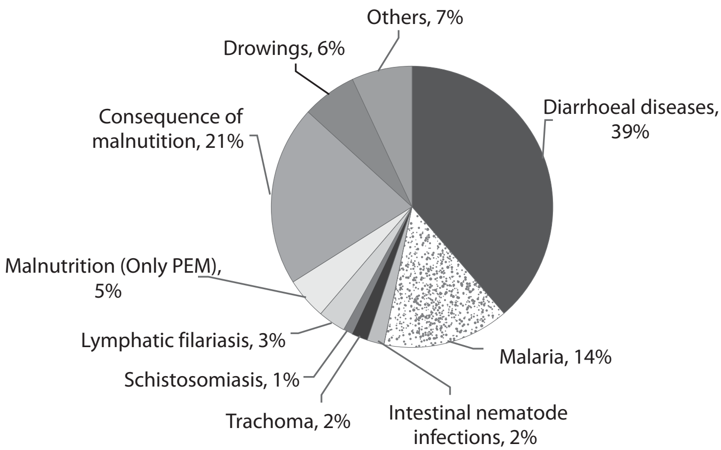


Figure 1.15: **Diseases contributing to the water, sanitation and hygiene related disease burden in DALYs**

In Bangladesh, around three-quarters of all diseases are related to unsafe water and inadequate sanitation. Each year 125,000 children less than five years old die of diarrhoea in Bangladesh, the under five years mortality rate is 92 per 1000 and the mortality rate of infant under one year is around 57 per 1000. In South Asia, countries having low sanitation coverage generally visage more diarrhoeal deaths (Figure 1.16). The sanitation coverage data of South Asian countries presented in the third South Asian Conference on Sanitation (Ratnayaka, Brandt et al.

2009) and the under five mortality rate reported in the State of the World's Children (Ratnayaka, Brandt et al. 2009) also suggest that the countries having good sanitation coverage have less under five mortality rate (Figure 1.17).

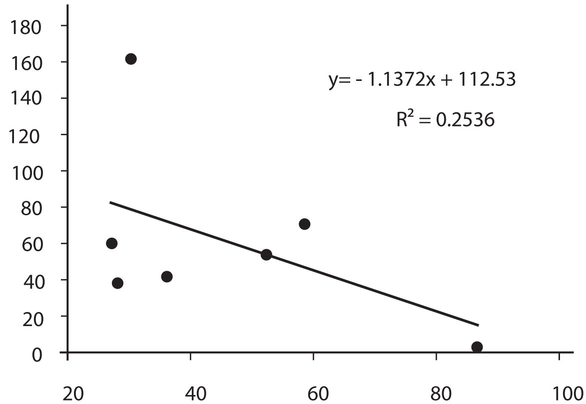


Figure 1.16: Sanitation coverage and diarrhoeal deaths in South Asian countries

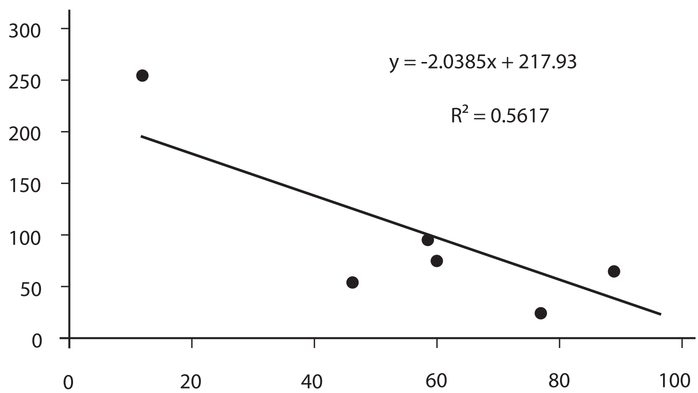


Figure 1.17: Sanitation coverage and under 5 mortality rate in South Asian countries

Figure 1.18 indicates that in Bangladesh with the increase in sanitation coverage as reported by SS the under 5 mortality rate decreases.

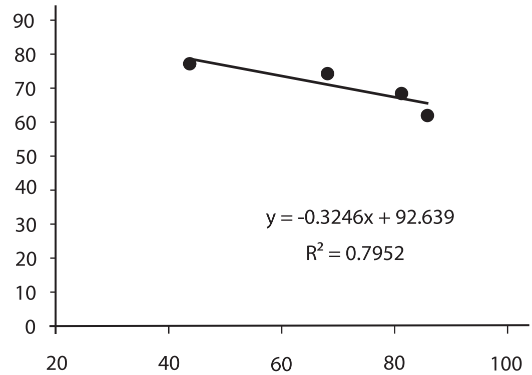


Figure 1.18: Sanitation coverage of Bangladesh and under 5 mortality rate in different years

In addition to loss of life, the physical and mental development of children is retarded by diarrhoea. Underweight in children under five years of age is directly responsible for some 1,000 deaths per year and total number of deaths caused directly and indirectly by malnutrition is 27,000 per year in Bangladesh. Improved water supply reduces diarrhoeal morbidity by between 6% and 25%.

Yearly around 143 million DALYs are lost in Bangladesh and 25 million population of the world are seriously incapacitated by lymphatic filariasis. In Asia lymphatic filariasis is transmitted by mosquito vectors breeding in water polluted by organic material. Trachoma is the leading cause of preventable blindness worldwide. An estimated 5 million people are already blind and a further 148 million suffer from active infections. It is transmitted primarily as a result of inadequate personal hygiene, and transmission can be reduced by facial cleanliness, access to safe water, adequate sanitation facilities, fly control and proper hygiene education. Schistosomiasis causes around hundred deaths per year in Bangladesh and affects 200 million people worldwide, with 20 million suffering severe consequences such as anaemia, impaired growth, poor cognition, and substandard school performance. Potential long-term effects include bladder cancer and serious kidney, liver or spleen complications. Schistosomiasis is caused by contact with water bodies contaminated with the excreta of infected people and is therefore fully attributable to unsafe water, inadequate sanitation or insufficient hygiene. International Union for Conservation of Nature, IUCN (2000) in reviewing epidemiological studies, found a median 77% reduction of schistosomiasis from well-designed water and sanitation interventions which prevent faeces and urine from entering surface water.

Half a million people die annually because of malaria and in Bangladesh the Figure is more than 600 per year. The fraction of malaria that might be eliminated through managing the environment such as water supply and sanitation (WSS) interventions varies across regions, with a global average of 42%. Dengue, causes more than 2,000 deaths per year in Bangladesh, is an acute infectious disease caused by the dengue virus and transmitted by the bite of infected mosquitoes and can be reduced by eliminating small water collectors and solid waste (around the home and in the community.

In West Bengal, India, out of 140,150 samples analyzed from all 19 districts, 48.1% had arsenic above 10 μg/L (the WHO guide line value) and 23.8% above 50μg/L that is the Indian standard value. Out of these 19 districts, nine districts (Malda, Murshidabad, Nadia, North-24-Parganas, South-24-Parganas, Bardhaman, Howrah, Hoogly and Kolkata), where more than 300 μg/L arsenic concentrations were found in tubewells are categorized as severely affected. Another five districts (Koch Bihar, Jalpaiguri, Darjiling, North Dinajpur and South Dinajpur) where the contaminated tubewells show arsenic concentrations mostly below 50μg/L (only a few above 50 μg/L but none above 100 μg/L), are categorized as mildly affected. Around 9.5 million and 4.6 million people in these 19 districts are at risk of drinking arsenic contaminated water having arsenic concentration exceeding 10 μg/L and 50 μg/L respectively.

In Bangladesh, the blanket screening test data of around 4.73 million tubewells (55% of total tubewells) in around 54 thousand villages (62% of the total villages) shows that groundwater from approximately 1.4 million (29% of tested) tubewells are contaminated with arsenic exceeding the concentration of 50 μg/L (Bangladesh standard for drinking water). DPHE-BGS-MML (1999) and BAMWSP (2001) studies reported that around 25% of their tested samples exceed the concentration of 50 μg/L and 42% tested samples exceed the concentration of 10 μg/L, provisional World Health Organization (WHO) guideline value for arsenic in drinking water. However, around 27% tested samples exceed the concentration of 50 μg/L and 46% tested samples exceed the concentration of 10 μg/L if only shallow tubewells are considered. It is evident from Rahman and Al-Muyeed (2009) that millions people in Bangladesh are at risk of arsenic poisoning from drinking groundwater contaminated with arsenic in excess of acceptable limit. (BGS and DPHE 2001) furnish two estimates of population exposure based on projected population of 125.5 million in 1999. The total population exposed to arsenic contaminated water above 50 μg/L and 10 μg/L are estimated as 32.5 million (25.9% of total population) and

56.7million (45.2%) respectively. Based on thana (lowest administrative unit) statistics the total population exposed to arsenic contaminated water above 50 μg/L and 10 μg/L are estimated as 28.1 million (22.4%) and 46.4 million (37%) respectively. The magnitude of the problem is increasing as more information is pouring in. Arsenic Policy Support Unit APSU (2005) reported around 38,000 arsenicosis patients in Bangladesh. Using US Environmental Protection Agency (EPA) model and distribution of population exposed to different level of arsenic, Rahman and Al-Muyeed (2009) estimated the incidence of excess lifetime skin cancer for different level arsenic contamination of drinking water in Bangladesh. The incidences of excess skin cancer are 0.29%, 0.043% and 0.012% for drinking arsenic contaminated water at existing level arsenic contamination, satisfying the Bangladesh Standard (50 μg/L) and satisfying WHO guideline value (10 μg/L) respectively. Hence the access to safe water is an urgent human need to minimize arsenic catastrophe in Bangladesh.

Improper handling of solid waste and health care waste (HCW) can result be transmission of Hepatitis and HIV diseases through infected objects, as well as other blood-borne pathogens such as malaria, ebola virus infection and haemorrhagic fever viruses (Rahman, Rahman et al. 2008). World Health Organization (WHO) estimated that, in year 2000, injections with contaminated syringes caused 21 million hepatitis B virus infections (32% of all new infections); 2 million hepatitis C virus infections (40% of all new infections); and, 260,000 HIV infections (5% of all new infections). Most countries of the developing world, particularly Bangladesh, lack regulation, and the knowledge about associated health hazards of the personnel involved in handling the HCW are very poor. The waste pickers in Bangladesh normally salvage every possible item of value from HCW with bare hands and feet and thus have been found the most vulnerable group exposed to serious health hazards. They do not have any access to information on the origin of the hazardous portion of HCW. Therefore, the urban poor in Bangladesh are potentially at serious risk because of malnutrition and poor living environment; and, particularly the poorest of the poor, the scavengers/ waste pickers, are in direct contact with the hazardous HCW as they are forced to work with this waste for their livelihood (Rahman et al. 2008).

Several diseases related to water, sanitation and hygiene could not be specifically quantifiable because of lack of adequate evidence. The impact of Climate Change will affect the temperature, rainfall, sea level, drought, flood, cyclone and storm surge, water quality, sanitation and other infrastructures. The diseases, those may be attributed to these erratic behavior of climate are cholera, diarrhoea, malaria, dengue, kala-zar, malnutrition, cardio-respiratory diseases. However at this stage hardly any data are available to predict the impact of those diseases because of climate change. Apart from that around 9.1% disease burden that is attributable to unsafe water, inadequate sanitation or insufficient hygiene may be an underestimate.

Water, sanitation and hygiene include a medium that can serve to transmit pathogens and toxic chemicals to drinking water very easily. Improvement of safe water supply, sanitation and hygiene practice has the potential to prevent at least 9.1% of the DALYs, or 6.3% of all deaths, globally. This also has a significant impact on children mortally due to the fact that children, particularly those in developing countries, suffer a disproportionate share of this burden. The fraction of total deaths or DALYs attributable to unsafe water, inadequate sanitation or insufficient hygiene is more than 20% in children up to 14 years of age. Potable water supply and improved hygiene and sanitation practices contribute significantly in reduction of diarrhoeal diseases (Table 1.12).

Table 1.12: Status of sanitary latrine in Bangladesh

Intervention area	Reduction in diarrhoea frequency
Hygiene	37%
Sanitation	32%
Water supply	25%
Water quality	31%

Sanitation reduces or prevents human faecal pollution of the environment, thereby reducing or eliminating transmission of diseases from that source. Hygiene promotion and health education are of paramount importance if any WSS programme is to be effective and sustainable. Hand washing is a critical part of hygiene behaviour. If people cannot afford soap as a mean to hand wash instead they can use ash.

1.12 Water Supply System

The broad objectives underlying any water supply system are: to supply safe and wholesome water to consumer, to supply water in adequate quantity, to make water easily available to consumers so as to encourage personal and household cleanliness.

In order that water should be safe and wholesome, it must satisfy the criteria of being least harmful upon consumption. A wholesome water is usually one which is unpolluted, free from toxic substances as well as excessive amounts of mineral and organic matter that may impair the quality of water. Standard of quality for drinking water have been established by many countries now to ensure that the water supplied is really safe and wholesome. The first objective as outlined above is fairly satisfying. To supply water adequate quantity would mean that the source of water supply must be so selected as to ensure that quantities of water as required by the community would be amply available, further, capacities of units required to store requisite quantities of water for continuous supply must be sufficient. To make water within the easy reach of consumers would mean planning a system of distribution involving pipes, valves and other fixtures of adequate design and capacity so that the system could be fully relied upon of meet the continual requirements of consumers at all hours of the day.

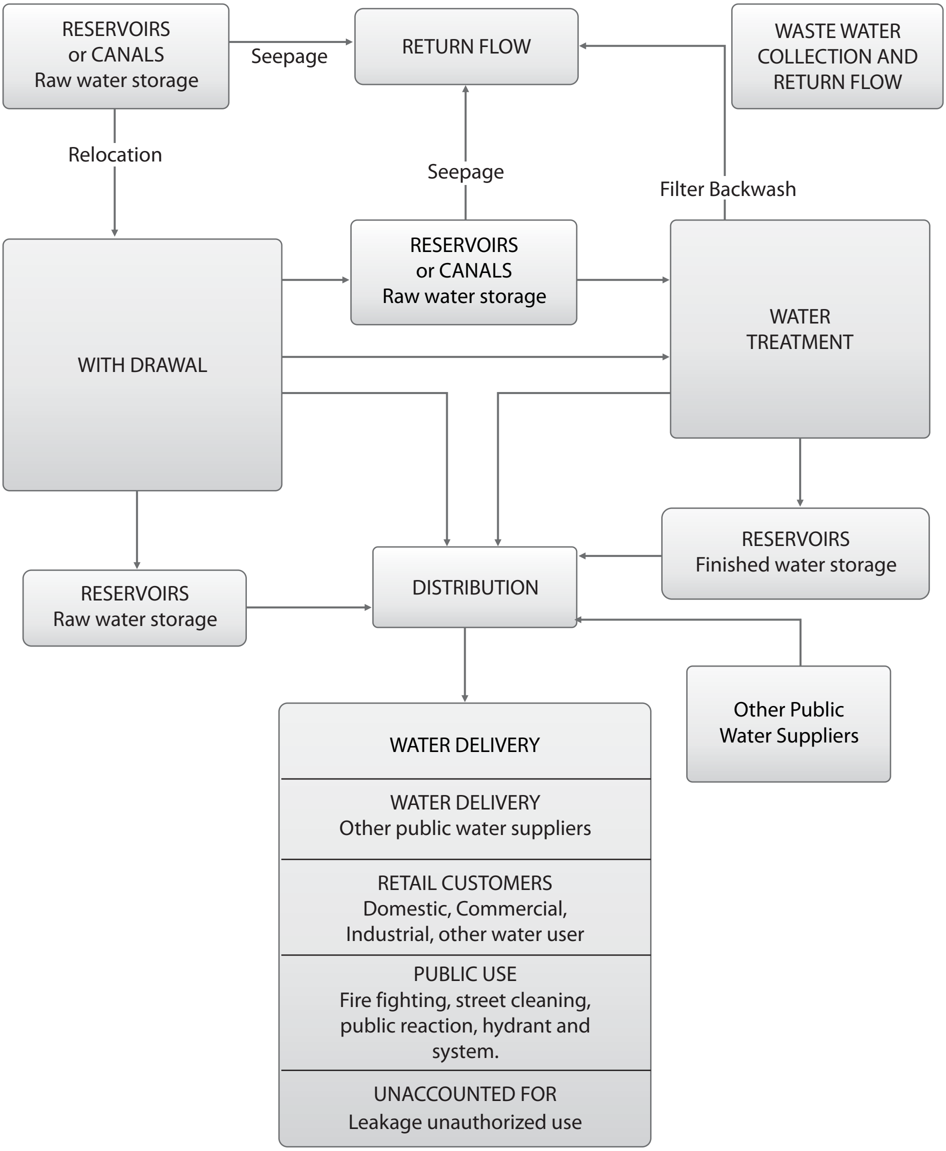
1.13 Public Water Supply

Public water supply refers to water withdrawn by public and private water suppliers and delivered to users. Public water suppliers provide water to domestic, commercial, and industrial users, to facilities generating thermoelectric power, for public use, and occasionally for mining and irrigation. A public water supply is a public or private water system that provides water to at least 25 people or has a minimum of 15 service connections. Examples of public water-supply systems include those that serve cities and towns, military bases, apartment complexes, and large mobile home parks.

The water-use activities in the public water-supply category include water withdrawal from ground and surface water; instream conveyance to and from reservoirs and canals; consumptive use, as evaporation during open storage or conveyance; raw and finished water storage; purchases from other public water suppliers; treatment; and distribution to other public water suppliers and to various users (Figure 1.19).

1.14 Elements of Public Water Supply

The water requirements of a modern city are so great that a system capable of supplying a sufficient quantity of potable water is necessary. The first step in the design of a water supply system is the determination of the quantity of water that



Consumptive use occurs as evaporation from open reservoirs and conveyances.
Reservoirs include open and covered reservoirs, tanks and towers.

Figure 1.19: Diagram of public water supply chain

will be required with provision for the estimated requirements of the future. Next a reliable source of water must be located, and finally a collection system, a treatment plant and a distribution system must be provided.

Water use varies from city to city depending on the population, climate conditions, industrialization and other factors. The planning of a water supply system requires that the probable water use and its variation be estimated as accurately as possible the essential elements of water supply system are as follows: source of supply, collection system, treatment of purification plant and distribution system.

1.14.1 Sources of supply

All water come in the form of precipitation. It is evaporated from the ocean, condenses to form clouds and finally precipitates over land. As the water falls in the form of rain or sleet or hail, it acts as a vacuum cleaner picking up all the dusts and dirt particles in air. Needless to say, the first water that falls from the clouds picks up the greatest concentration of contaminates. After a short period of fall, the precipitation is relatively free of contaminants. When the water hits the ground, a portion of its runs off across the surface of the ground and a portion of its sinks into the ground. Therefore, the source of supply is of two types: Surface water supply and Ground water supply.

Surface water supply: the water running across the surface of the ground has been designated as surface water. It picks up many substances as it flows back to the ocean like micro-orgasim, organic matter, minerals and other polluting substances. Surface water supply is generally obtained from streams, lakes, ponds, reservoirs and oceans. Since surface water is highly polluted it needs extensive treatment.

Ground water supply: the surface water which seeps into the ground is designated as ground water or sub-surface water. It travels through the surface layers of the earth; it picks up some minerals and a few organics in solution. The micro-organisms and particulate matter find themselves being filtered out in the upper layers. Thus it is found that most ground waters taken far below the earth's surface are free of micro-organisms. These waters are usually relatively low in mineral and organic contaminants. Needless to say, ground waters are usually preferred as sources of drinking water to surface waters. Springs, wells and galleries form the chief ground water supply. The Figure 1.20 shows the different sources of water.

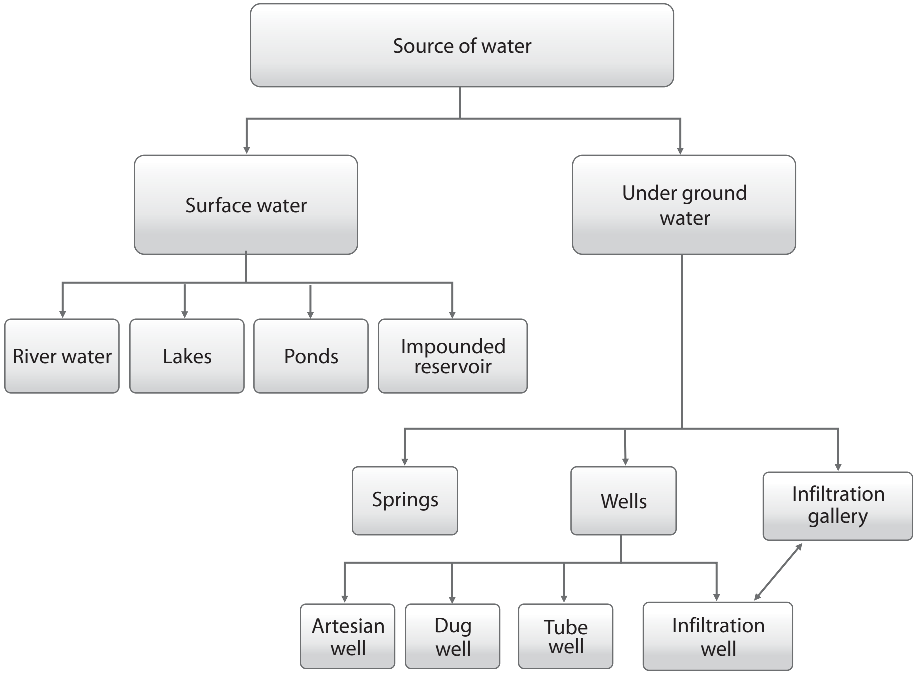


Figure 1.20: Different sources of water

1.14.2 Suitability of sources with regards to quantity and quality

Quantity: As the effect of rainfall is most direct on the surface sources of water supply, the quantity of water available is abundant. However, since the rainfall may not be uniformly spread throughout the year especially in the case of tropical countries like Bangladesh and India, considerable variations in the flow of surface water are likely. Thus the flow in the stream or rivers may vary from a maximum during the rainy season, sufficient to result in floods to a minimum during dry months, sufficient to cause long droughts. In case of impounding reservoirs, in addition to the rainfall and runoff, the tropography of the catchment area is important. It should be such as to drain off water from all remote points.

As regards the underground sources, the quantity of water available is usually less than that in the case of surface sources; the effect of rainfall now being most indirect, and depending upon the available underground storage and the geological formations of the substrata i.e, permeable or non-permeable. In case shallow wells and springs, it is easier to get supplies by tapping the upper water bearing strata but such storage may be temporary and fall of during dry season resulting in failure of the source. The underground supplies drawn from greater depths i.e. deep wells are more constant in their yield and hence more reliable.

Quality: impurities in water normally are of two types, suspended and dissolved. The surface waters are characterized by the suspended impurities whereas the ground waters are generally free from the suspended matter but are likely to contain a large amount of the dissolved impurities, which they gather during the course of their travel in the underground strata comprising of rocks and minerals. The suspended matter often contains the pathogenic or diseases producing bacteria; as such surface waters are not considered to be safe for water supply without the necessary treatment. Ground waters are comparatively safer and fit for use with or without minor treatment only. The rain water is soft, has a flat taste and is free from contamination. The river water varies in quality. This variation is caused by the great difference in the maximum and minimum flow. The maximum flow is caused by high floods, resulting in an increase in turbidity and bacteria due to the surface wash brought into the river. The minimum flow is due to the flow of ground water into the river, resulting in the decrease of turbidity but increase of dissolved impurities. The river water therefore must be thoroughly treated before supplying for public use. Impounding reservoir storage water by the construction of a dam across a natural water course. The storage providing may be as much as 60 days or less. This long storage enables the suspended matter to settle down and be removed. There is also considerable reduction in harmful bacteria and in colours present.

The quality of ground water is comparatively much better. This is due to the fact that water gets strained during its passage through the porous underground strata. The geological formations with which water comes into contact also impart to it certain qualities like softness or hardness. The bacteria content of waters from springs, infiltration galleries and deep wells is usually low due to the staring action involved.

1.14.3 Choice of a source for water supply

Considerations in the selection of a particular source for supplying of water are: Quantity, Quality, and Cost.

- Quantity of water available from the source should be sufficient to cater for the needs of the town or city regarding domestic service, industrial demands, fire fighting requirements and other public uses.

- Quantity of water supplied should also include the design requirements, which means the calculated quantity would be somewhat higher than the bare needs. The quantity and quality of water are prime considerations in the selection of any source of supply.
- Cost considerations regarding the development and operation of water supply are also significant. The cost of supply would depend whether the system of supply are also significant. In short the cost of water supply would depend whether the system of supply is owned by gravity from the source or it has to be pumped first before supplying. The cost shall also depend upon the distance between the source of supply and the distribution system. Longer distance means greater cost of conduits and other appurtenances required. In short, the cost of water supply must be reasonable compared to the number of people served and must bear a fair relation to the value of property served so that by equitable taxes and reasonable charges for water, the original cost of the system can be repaid at the end of the design period, which is usually 20 to 30 years.

1.14.4 Collection system

The collection system is a sort of engineering works designed to convey from a source to a treatment plant. The following are essential units in a collection system: Intake, Intake main, Aqueduct or Transmission main, and Pumping station.

Intake: An intake is a device or a structure placed in a surface water source to permit the withdrawal of water from this source and its discharge into an intake conduit or pipe through which it will flow into the water works system. Type of intake structures consist of intake towers, submerged intakes, intake pipes or conduits, movable intake and shore intakes. Intake should be so located and designed that the possibility of interference with the supply is minimised to the greatest possible extent. Where uncertainty of continuous serviceability exists intakes should be duplicated. The following factors must be considered in designing and locating intakes: Location of the best quality of water available, Possibility of wide fluctuations of water level, Characteristics of intake surrounding, i.e. depth of water, character of the river bottom, navigation requirements, the effects of waves, currents, floods, and storms upon the intake structure and in scouring the river bed and banks, formation of shoals and bars, Possible sources of pollution, and provision for excluding possible floating materials like logs and vegetations.

Intake main and transmission main: A pipe line must be used to deliver the water from the source to the treatment plant. The kind of pipe to be used cast iron, steel, concrete, asbestos cement, or even wood will depend to some extent on local conditions and local costs, which should be determined on an engineering basis. Similarly, the size of the pipe is fixed by the volume of water to be delivered and the pressure or head of water. In general, the design of the pipe line will be governed by the principles of engineering economics, perhaps to a great extent than any other part of the water supply system.

Pumping Station: A pumping station is essential for pumping water from the source through the intake to allow water to flow by gravity through the transmission main to the treatment plant.

1.14.5 Treatment plant

Water as it is drawn from streams, reservoirs, or wells, is rarely suitable for use. It must usually be treated before it reaches the consumers. In case of surface water the treatment procedure may involve the removal of turbidity, colour, taste, odour, and bacteria. Ground water from wells may be treated to reduce hardness, iron, corrosive qualities, and sometimes bacteria. The methods used for treatment include screening, sedimentation, treatment with chemicals, filtration through sand beds, and disinfection to kill micro-organisms. Most streams are polluted by industrial or domestic wastes to some degree and treatment of the water from a stream must be designed to provide safe, clear and palatable water under any condition. Adequate treatment is necessary because the use of polluted water can be an important factor in the spread of many diseases.

1.14.6 Distribution system

The distribution system is needed to deliver water to the individual consumer in the required quantity and under a satisfactory pressure. The distribution system is often a major investment of a municipal water-works. This includes: Various pipes that convey the water to the consumer, Storage reservoirs that are provided to aid in the distribution of water, Pumps and necessary equipments, and Fire hydrants, valves, meters, and other appurtenances.

Classification of distribution system: there are three general methods or systems for furnishing satisfactory water pressure in the distribution pipes, namely, the gravity system, the distributing reservoir system, and the direct pressure system. In a gravity system the source of supply is at such an elevation with respect to the community to be served that adequate pressure in the pipe is obtained directly from the head. In a distributing reservoir system, the water is pumped to a reservoir called a storage reservoir or distributing reservoir which is at such an elevation that the water flows by gravity through the mains. The procedure in designing a distribution system is essentially the same in each case. The details of the system are determined largely by cost and local topographic characteristics.

Pressure requirements in distribution pipes: For general domestic purposes the necessary pressure of water in the pipes, which is usually indicated by an ordinary pressure gauge is about 50 to 60 psi. However, in communities built in hilly or mountainous districts, considerable variation in pressure may be necessary in the pipe lines. In general, the pressure for domestic purposes should not fall below 20 psi and should not exceed 120 psi. Where the condition is such that variation in pressure would otherwise exceed the given limits, it is necessary to layout the distribution system in separate districts of high and low pressure. To supply water to all floor in a very high multi-storied building, it is necessary to install separate pumps and roof top tanks in the building.

Fire service requires pressure higher than that provided for domestic use because the water is used at a greater rate and, to be effective in fighting fire, the water must issue from the nozzle of a fire hose with a sufficient velocity to a considerable height. When the pipe pressure is dependent on the forcing water through a hose to a fire, a pressure of at least 80 to 100 psi is needed in the pipes. Many other engineering problems, the question of pipe pressure requires for its solution a careful weighting of conditions and costs.

Distribution reservoirs: These reservoirs are used to provide storage of treated water to meet the water requirement of the consumers and also to provide fire storage and to stabilize pressure in distribution system. The reservoirs may be square. The reservoirs should be located as close to the center of use as possible. The water level in the reservoir must be high enough to permit gravity flow at satisfactory pressure to the pipe system it serves.

Pumping station: A pumping station is needed to pump water to the reservoir to allow the water to flow by gravity to the distribution system.

Distribution system: The basic requirements of distribution system are adequate strength and maximum corrosion resistance. Cast iron, concrete, asbestos cement, PVC and G.I. pipes compete in smaller sizes, while steel, and R.C.C pipes compete in larger sizes.

All the essential elements of a water supply system for a city is diagrammatically shown in Figure 1.21

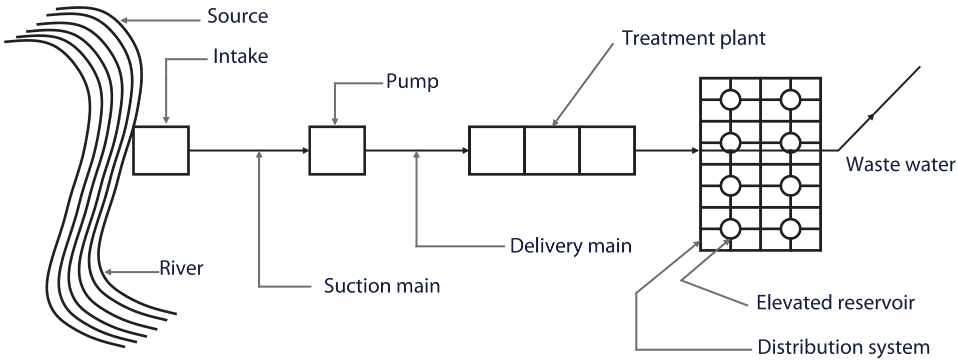


Figure 1.21: **Essential Elements of Water supply System**

1.15 Planning a Municipal Water Supply System

Communities with a municipal water supply in the metropolitan/municipal area are required to prepare water supply plans as part of their communities' local comprehensive plans. Usually it is global practice that public water suppliers that serve more than 1,000 people must also have their water supply plan. There are some comprehensive guidelines while planning municipal water supply system. These guidelines are usually divided into three major parts:

Water supply system description and evaluation: In this step, the following considerations are required.

- Data collection/assessment of historic (usually past 10 years) water demand in each type of water use; i,e., residential / institutional / commercial / industrial / unaccounted
- Identifying the sources of water; i, e, all groundwater. Surface water and interconnections that will supply water to the system
- Estimation of demand projections where the assumptions for per capita, per household or any other method should be mentioned while served population for water supply will be predicted.

- Suitable collection system should be identified and then implemented the right technology.
- Proper treatment technology / process for raw water need to identify and capacity of water treatment plant will be designed accordingly. In this instant, annual amount and method of disposal of treatment residuals need to address as well.
- Provision for the necessary storage of water, and design of the works required to deliver water from its source to the community will be assessed.
- Designing distribution system, including distribution reservoirs, pumping station, elevated storage, layout and location of fire hydrants are need to address in the plan.
- Sustainability of resource is important as records / monitoring of water levels should be maintained for all production wells and source water reservoirs / basins. Therefore, use of water to provide for the needs of society, now and in the future, without unacceptable social, economic, or environmental consequences need to confirm.
- Capital Improvement Plan (CIP) also includes in this step, which assesses
  - Adequacy of water supply system where water supply installations, treatment facilities and distribution system are checked to sustain current and projected demands and it also describe any potential future capital involvement.
  - New alternate sources of water / wells/ intake.
  - Long term preventive measures and programs that will reduce the risk of emergency situation when the system might prone to failure due to age, materials or other problems.

Emergency response procedure: Water emergencies can occur as a result of vandalism, sabotage, accidental contamination, mechanical problems, power failures, drought, flooding and other natural disaster. The purpose of emergency planning is to develop emergency response procedures and to identify actions needed to improve emergency preparedness. It includes

- Emergency telephone/contact list that include key utility and community personnel, contacts in adjacent communities. In the case of municipality, this information should be contained in a notification and warning standard operating procedure maintained by the warning point for that community.

- A detailed map of water supply system showing the treatment plants, water sources, storage facilities, supply lines, interconnections and other information that would be useful in emergency should be readily available during emergency.
- Listing all available sources of water that can be used to augment or replace existing sources in an emergency. In the case of municipality, this information should be contained in a notification and warning standard operating procedure maintained by the warning point for that community.
- Allocation and demand reduction procedures should be incorporated in the plan where procedures to address gradual decreases in water supply as well as emergencies and the sudden loss of water due to line breaks, power failures, sabotage, etc. During periods of limited water supplies public water supplies are required to allocate water based on the priorities. As example, vehicle washing is less priority than domestic water supply.

Water conservation plan: Water conservation programs are intended to reduce demand for water, improve the efficiency in use and reduce losses and waste of water. Long term conservation measures that improve overall water use efficiencies can help reduce the need for short-term conservation measures. It includes proper metering of consumption, accounting the unaccounted water, conservation water rates, implementing regulations, education & information programs.

1.16 Conclusion

Engineers and scientists work to secure water supplies for potable and other uses. They evaluate the water balance within a watershed and determine the available water supply, the water needed for various needs in that watershed, the seasonal cycles of water movement through the watershed and they develop systems to store, treat, and convey water for various uses. Water is treated to achieve water quality objectives for the end uses. In the case of potable water supply, water is treated to minimize the risk of infectious disease transmission, the risk of non-infectious illness, and to create a palatable water flavor. Water distribution systems are designed and built to provide adequate water pressure and flow rates to meet various end-user needs such as domestic use, fire suppression, and irrigation. However, in order to maintain the stream of ecology, biodiversity in maintaining favourable climate change, water supply and demand science/engineering/management is utmost important which are successively discussed in this book.

Reference

Alroy, J., C. R. Marshall, et al. (2001). "Effects of sampling standardization on estimates of Phanerozoic marine diversification."Proceedings of the National Academy of Sciences of the United States of America 98: 6261-6266.

AWWA (1976). History of Public Works in the United States. Chicago, American Public Works Association, Chicago.

Baker, M. N. (1949). The Quest for Pure Water. New York, American Water Works Association.

BGS and DPHE (2001). BAMWSP 2001 Status Report of Bangladesh Arsenic Mitigation Water Supply. Dhaka, Project BAMWSP December.

Bond, F. C. (1952). "The Third Theory of Communication."Transactions of the American Znstitute of Mining Engineers 193(484).

De Camp, L. S. (1963). The Ancient Engineers. New York, Doubleday.

IUCN (2000). Redbook of threatened animals of Bangladesh. Dhaka, IUCN Bangladesh.

J.K, G. and H. Editor-in-Chief:Â Â Kris (2008). Waterborne Diseases. International Encyclopedia of Public Health. Oxford, Academic Press: 551-563.

Kirby, R. S., S. Withington, et al. (1956). Engineering in History. New York, McGraw-Hill.

Lankton, L. D. (1977). "1842: The Old Croton Aqueduct Brings Water, Rescues Manhattan from Fire, Disease." Civil Engineering 47(10).

Mara, D. D. and R. G. A. Feachem (2003). 11 - Unitary environmental classification of water-and excreta-related communicable diseases. Handbook of Water and Wastewater Microbiology. London, Academic Press: 185-192.

Oâ€™Keefe, P., J. Rose, et al. (2008). Relief Operations. International Encyclopedia of Public Health. Oxford, Academic Press: 506-513.

Popper, F. J. (1985). "The Environmentalist and the LULU."Environment 27(7).

Rahman, M. H. (2002). "Management of Industrial Wastewater in Bangladesh."Proc. of the 12th Stockholm Water Symposium (Abstract Volume).

Rahman, M. H. and A. Al-Muyeed (2009). "Application of Rainwater Harvesting Technology in the Pastoral Bangladesh."Proc. of the 19th Stockholm Water Symposium, (Abstract Volume), Sweden, 2009: 235-236.

Rahman, M. H. and D. H. Bache (1993). "Bound Water Content of Digested Sludge."Resource Management and Technology 21(3): 142 - 148.

Rahman, M. H., A. Rahman, et al. (2008). "Health Care Waste Management Issues in Bangladesh."Proc. of the 23nd International Conference on Solid Waste Technology and Management, Philadelphia.

Ratnayaka, D. D., M. J. Brandt, et al. (2009). CHAPTER 1 - The Demand for Public Water Supplies. Water Supply (Sixth Edition). Boston, Butterworth-Heinemann: 1-35.

Ridgway, J. (1970). The Politics of Ecology. New York, Dutton.

Turk, A. e. a. (1974). Environmental Science. Philadelphia, W.B. Saunders.

WHO (1998). The World Health Report.

WHO, U. a. (2008). Sanitation (SACOSAN 2008). India in New Delhi.

Wisely, W. H. (1974). American Civil Engineer. American Society of Civil Engineers. New York: 1965-1974.