



Alternative Water Sources and Wastewater Management

E.W. Bob Boulware

ISBN-13: 978-0-07-171951-3

MHID: 0-07-171951-2

Chapter 1: Introduction

This important chapter is representative of the authoritative content available on McGraw-Hill Education's

AccessEngineering, the award-winning engineering reference tool for professionals, academics, and students. It provides fully searchable text optimized for the web with exclusive, faculty-created, how-to videos, curriculum maps tied to core content, plus calculators, interactive graphs, and downloadable tables.

For information regarding trial access, pricing, or placing an order, please contact us at:

Email: stsales@mhprofessional.com

Telephone: 1.877.840.2297 (US)

1.614.759.3663 (Outside the US)



CHAPTER 1

Introduction

Access to clean water can be considered one of the basic needs and rights of a human being. The health of people and a dignified life are based on access to clean water and proper sanitation. It can be said that together these two tenants are key to the health and economic prosperity of a civilized society.

According to WHO and UNICEF, 82 percent of the world's population has access to an adequate water supply (Fig. 1.1). The amount of proper sanitation has increased from 49 percent in 1990 to 58 percent in 2002. Still, approximately one out of six (1.1 billion people) are lacking access to an adequate water supply, and two out of five (2.6 billion people) are without access to proper sanitation services (Fig. 1.2). Most of these people live in areas of Asia, where as much as half of the population lack proper sanitation services, and in areas of Africa, two out of five do not have access to an adequate water supply. The situation is especially alarming in rural areas, where half of the people do not have access to proper sanitation and water supply services. In bigger cities, the problem is intense population growth and concentration on population centers. This will burden existent services in the decades to come.^{1,2}

In most parts of the world, freshwater is transported from another region or location by boat, train, truck, or pipeline. The source of this water can be from a spring, well, lake, or river. As demand for clean water increases and sources become more limited due to expanding pollution, alternative sources of water and waste management need to be found.

Freshwater supplies are unlikely to keep up with global demand by 2040, which will cause increasing political instability, hobbled economic growth, and endangered world food markets, according to a U.S. intelligence assessment.³ This book gathers together technologies and ideas from around the world to illustrate alternative ideas for providing clean drinking water when local utility water or waste management systems are not available.

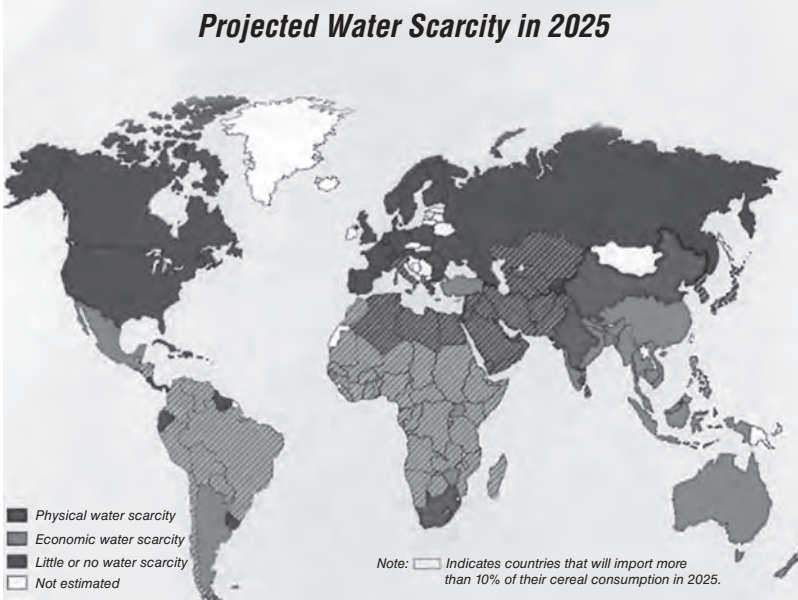


FIGURE 1.1 Water stress: 1.2 billion people—or almost 1 out of 5 people in the world—are without access to safe drinking water, and half of the world’s population lacks adequate water purification systems. (See also Color Plates.)

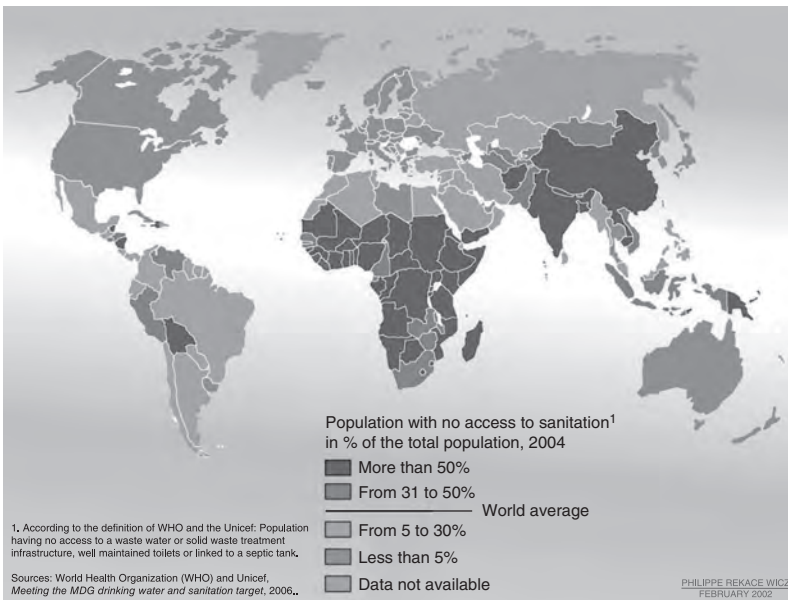


FIGURE 1.2 Sanitation stress: Compounding the shortage of water is that 40 percent of the world’s population, 2.4 million people, does not have access to proper sanitation, which further decreases the availability of safe drinking water.

The Water Cycle

The water cycle describes the existence and movement of water on, in, and above the earth. Earth's water is always in movement and is always changing states, from liquid to vapor to ice and back again. The water cycle has been working for billions of years, and all life on earth depends on it continuing to work. In spite of water shortages that are being experienced worldwide, it is important to note that there is still the same amount of water on the planet as there was when dinosaurs roamed the earth.

All water is rainwater. Conventional wisdom in the Western world is to intercept the water after it has picked up debris and chemicals as surface runoff flowing across the ground, and then picked up more chemicals from our rivers and streams. Then it is filtered to take out the debris, and more chemicals are added to make it potable. Chapters 2 through 10 of this book explore other options of obtaining fresh water used successfully elsewhere in the world.

Of the water in the world water supply, 97 percent is salt water. Of the 3 percent that is freshwater, most is locked up in the ice caps, deep subsurface deposits, and in the atmosphere. Actual available water that is readily obtainable is less than 1 percent (Fig. 1.4). And with increasing pollution, this 1 percent is a diminishing asset. Sometimes there is too much water (floods), and sometimes there is too little (drought). Given the apparent problematic nature of water, it seems advisable to take a new look at our water use and where our water needs are to come from.

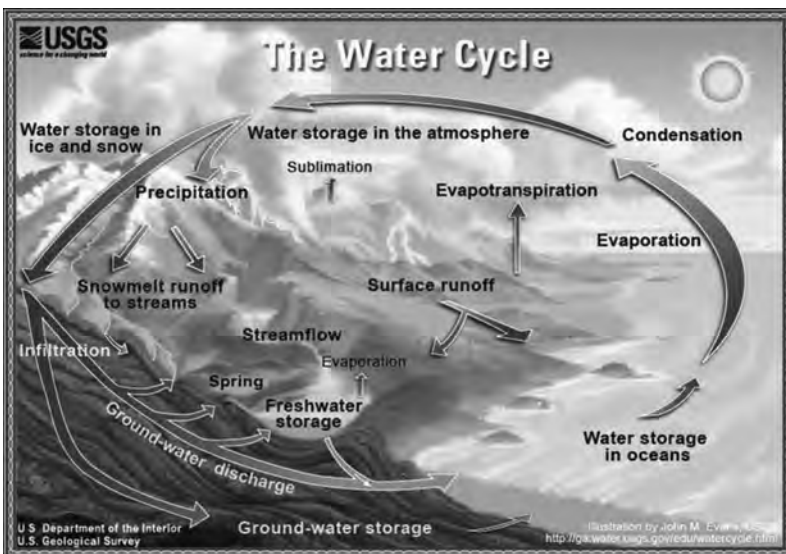


FIGURE 1.3 Water cycle. (See also Color Plates.)

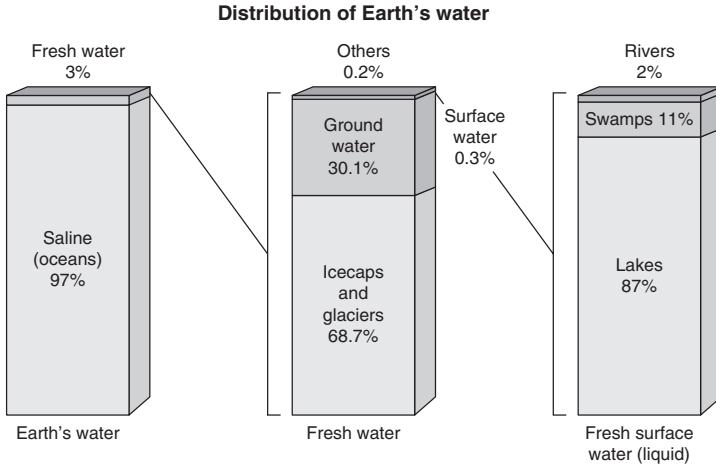


FIGURE 1.4 Distribution of earth's water.

It is instructive to note that, with the exception of food service buildings, very little water consumed in commercial buildings needs to be potable water (Fig. 1.5). For residences, potable water consumption is approximately 15 to 20 percent of the water consumed (Fig. 1.6). Clearly, opportunities exist for more efficient use and reuse of water provided to our facilities.⁴

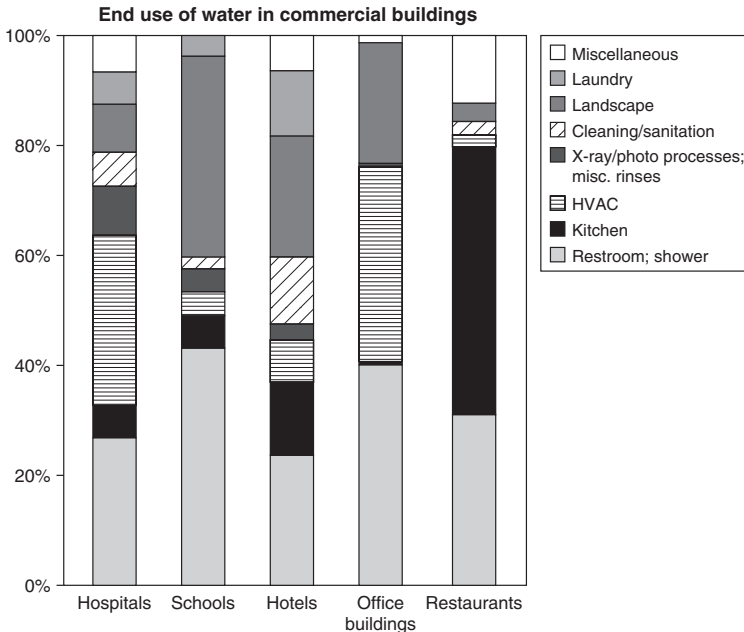


FIGURE 1.5 Water use profile for various buildings.

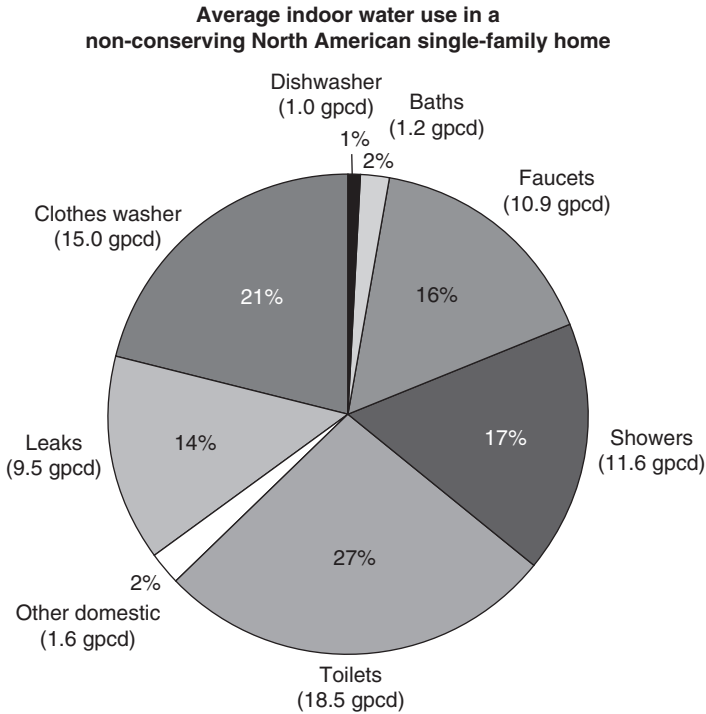


FIGURE 1.6 Water use profile for residential facilities.

Benjamin Franklin said, “You only know the value of water when the well runs dry.” The world’s well *is* running dry on many parts of the planet. Determining what alternatives and opportunities exist if you find your particular well running dry is the purpose of this book.

How Much Water Is on Earth?

The spheres in Fig. 1.7 represent all of Earth’s water, Earth’s liquid fresh water, and water in lakes and rivers. The largest sphere represents all of Earth’s water, and its diameter is about 860 miles (the distance from Salt Lake City, Utah, to Topeka, Kansas). It would have a volume of about 332,500,000 cubic miles (mi^3) (1,386,000,000 cubic kilometers (km^3)). The sphere includes all the water in the oceans, ice caps, lakes, and rivers, as well as groundwater, atmospheric water, and even the water in you, your dog, and your tomato plant.

Liquid Fresh Water

How much of the total water is fresh water, which people and many other life forms need to survive? The blue sphere over Kentucky

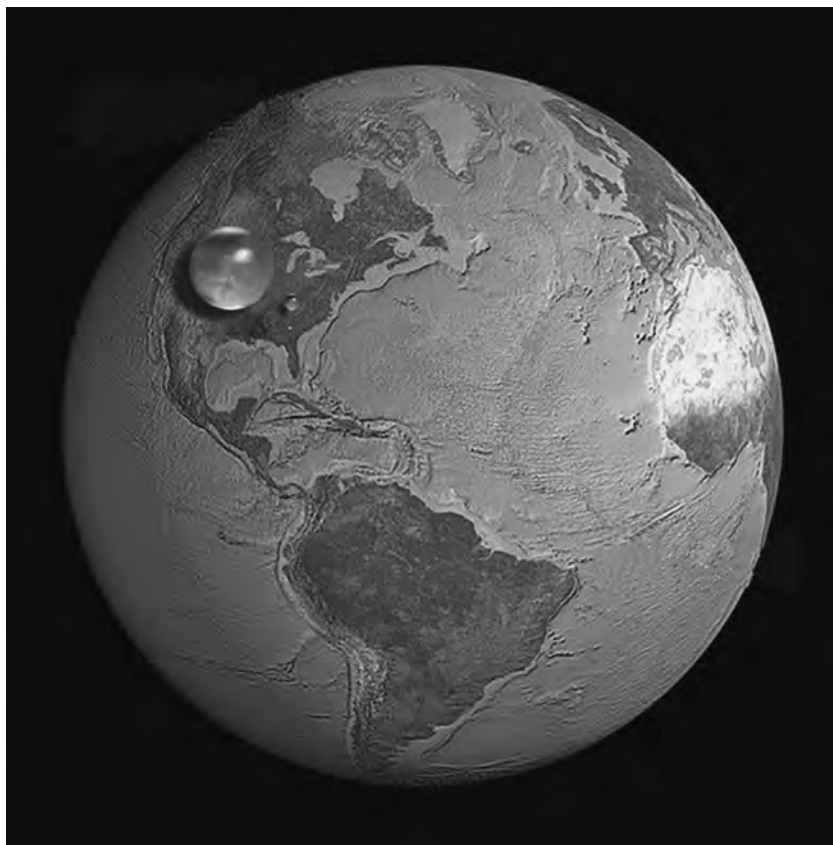


FIGURE 1.7 How much water is on earth? (See also Color Plates.)

represents the world's liquid fresh water (groundwater, lakes, swamp water, and rivers). The volume comes to about $2,551,100 \text{ mi}^3$ ($10,633,450 \text{ km}^3$), of which 99 percent is groundwater, much of which is not accessible to humans. The diameter of this sphere is about 169.5 miles (272.8 kilometers).

Water in Lakes and Rivers

And that "tiny" bubble over Atlanta, Georgia? That one represents fresh water in all the lakes and rivers on the planet, and most of the water people and life of earth need every day comes from these surface-water sources. The volume of this sphere is about $22,339 \text{ mi}^3$ ($93,113 \text{ km}^3$). The diameter of this sphere is about 34.9 miles (56.2 kilometers). Yes, Lake Michigan looks way bigger than this sphere, but you have to try to imagine a bubble almost 35 miles high—whereas the average depth of Lake Michigan is less than 300 feet (91 meters).³

Sources of Water

Water sources are manifold. Many communities get their water from reservoirs. In 500 B.C.E., the Greeks supplemented local city wells with water supplied from the mountains as far as 10 miles away. In later times, the Romans built aqueducts that were many miles long—there were more than 200 that were still standing in the year 2001. Cities and other communities often provide for their water supply by allocating an open area that is pristine and protected as a watershed. The water was usually of high quality and free from chemical and microbial contamination.

The energy associated in producing clean water suitable for drinking is often overlooked. This can vary from between 1.6 kW/1000 gallons (3800 liters) for well water to 12 kW/1000 gallons for desalination of seawater (Fig. 1.8). Conversely, it is illuminating to see the amount of water consumed in generating electric power (Fig. 1.9). Clearly, if we continue the existing way of managing our water, the overall result will be that the quality of our waters will further deteriorate and the availability will decline.

In certain parts of the world, water is supplied to communities from groundwater sources from deep wells, often many thousands of feet down. Water from these sources is usually free of chemical and microbial contamination. Groundwater is the main source of drinking water for almost half of the population in the United States. It is relatively inexpensive but is limited in volume and sometimes not readily replaceable if demand exceeds supply.⁵ The Ogallala Aquifer,

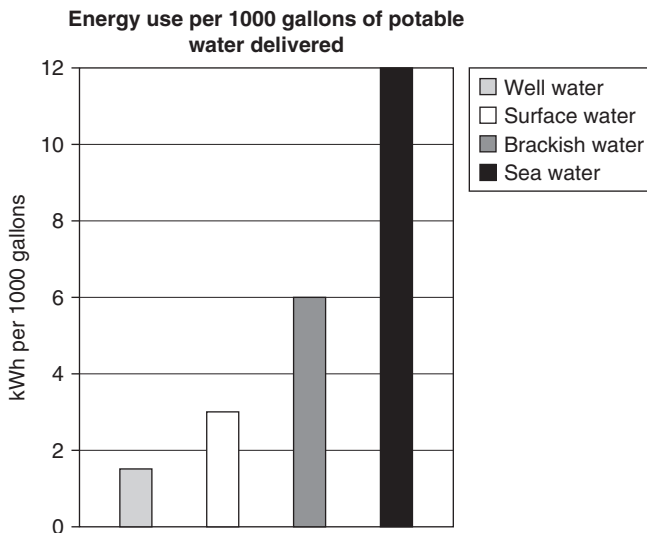


FIGURE 1.8 Energy consumption to generate potable water.

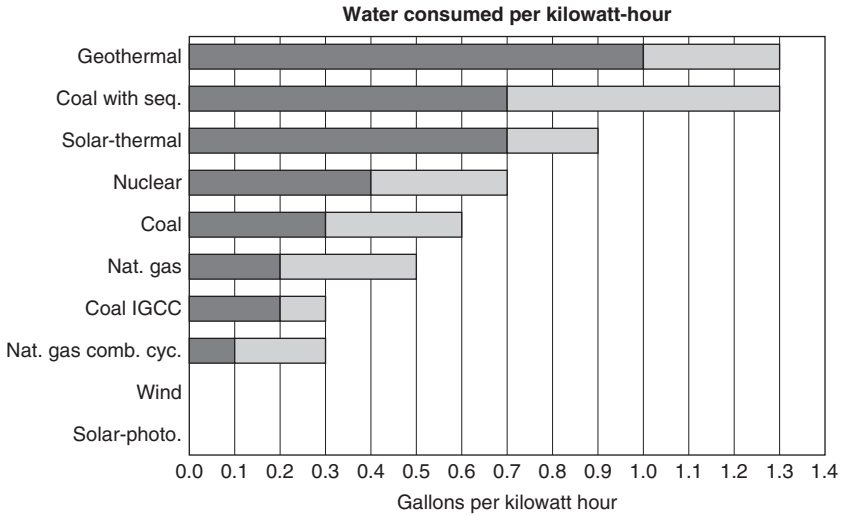


FIGURE 1.9 Amount of water consumed to generate electric power.

which is the sole source of water in the central western part of the United States, is said to have first been tapped in 1911 by a hand-dug well. Now an estimated 12 billion cubic meters of water is removed from the aquifer each year. Because it would take 6000 years to replace the water in the Ogallala Aquifer, it is expected that 6 percent of the aquifer will dry up every 25 years, leaving the residents and farmers of the Great Plains unsure about how long their water supply will last.⁶

While well water is usually free of solids and bacteria, as well as other chemical pollutants, it has often become contaminated by disposal of liquid waste, mining operations, and agricultural runoff. By providing protection to the source, either through buffers from the reservoirs or by protecting the well head for the deep wells, water is available without much treatment.

However, with increasing population and the increased use of water, there are less uncontaminated water supplies available. It is now commonplace that water must be treated prior to consumption. Disinfection is an important step in the water treatment process to destroy pathogenic bacteria and other harmful agents. Most water is treated with chlorine, as it is a very effective and economical method of treatment. An important advantage to using chlorine is that it has residual properties and continues to provide germ-killing potential as the water travels from the distribution point to the end users. There are concerns, however, about the formation of disinfection by-products from the reaction of the chlorine with humic substances in the water. These by-products are referred to as trihalomethanes, or THMs. The most common THM is chloroform, which is a carcinogen. In addition,

some of the bacteria and viruses we want to treat are becoming resistant to traditional means of disinfection.

So it is apparent that the customary water supplies are becoming more and more inadequate, from both a quality and quantity point of view. To supplement the traditional sources of water, the following alternative ideas, which have been used successfully, will be presented for your consideration and evaluation:

- Springs
- Air conditioning condensate recovery
- Dew harvesting
- Fog harvesting
- Glacier water harvesting
- Rainwater catchment
- Solar water still
- Gray water systems

Sanitation and Waste Management

Sanitation includes the appropriate disposal of human and industrial wastes and the protection of the water sources. Waterborne agents are the cause of many diseases in the United States and elsewhere in the world.⁷ These diseases may be caused by bacteria, viruses, and protozoans. Bacterial diseases include typhoid, shigellosis, and cholera. Viral agents cause diseases such as polio and hepatitis. Parasites include the protozoa *Entamoeba histolytica* and *Giardia lamblia*, which cause amebiasis and giardiasis, respectively. For the last decade, the primary agents in waterborne disease outbreaks in the United States have been the protozoal parasite *Giardia* and the bacteria *Shigella*. Another common agent is *Cryptosporidium*. Sanitation and water supply are interrelated issues that until now have been treated as separate issues. Looking forward, management of the entire water cycle will be needed.

Sanitation and Water Pollution

Sanitation is directly related to water quality and water pollution. The basic concept of collecting domestic liquid waste in waterborne sewer systems, treating the wastewater in centralized treatment plants, and discharging the effluent to surface water bodies became the accepted approach to sanitation in the last century. Although conventional sewer systems have significantly improved the public health situation for the communities that can afford to install and operate them, continued use adds pollution to our water supplies and reduces the purity of water

needed for potable application later. This is becoming a worldwide problem, not only for the developing world with its inadequate sanitation, but also for the developed world with its aging infrastructures that cannot meet the needs of an increasing population.

The conventional sewer system was developed at a time, in regions, and under environmental conditions that made it an appropriate solution for removing liquid wastes from cities. Today, with increased populations, changes in consumer habits, and increasing pressure on freshwater and other resources, this human waste disposal system is no longer able to meet the pressing global needs. Thus, newer ideas need to be developed to address the issue of water quality conservation along with better means of waste disposal that do not pollute our water sources.

As serious as the disadvantages of water-based sanitation systems are, a far more fundamental problem is that they allow the nutrients in the wastewater to become a liability to the health of humanity rather than an asset. This lack of nutrient recovery leads to a linear flow of nutrients from agriculture, via humans, to recipient water bodies. The valuable nutrients and trace elements contained in human excrement are very rarely rechanneled back into agriculture in conventional systems. Even when sewage sludge is used in agriculture, only a very small fraction of the nutrients contained in the excrement are reintroduced into the living soil layer. Most are either destroyed in the treatment process (e.g., by nitrogen elimination) or enter the water cycle, where they pollute the environment and cause the eutrophication of lakes and rivers.

Not returning the nutrients to the soil has led to an increasing demand for chemical fertilizers in response to the problem of decreasing soil fertility. To produce the required chemical fertilizers, large amounts of energy are needed, and finite mineral resources, such as phosphorous, must be exploited. Farmers around the world yearly require 135 million tons of mineral fertilizer for their crops, while at the same time conventional sanitation dumps 50 million tons of fertilizer equivalents into our water bodies.

Sanitation and the Future

Our conventional drinking and wastewater systems are largely linear, end-of-pipe systems where drinking water is misused to transport waste into the water cycle, causing environmental damage and hygienic hazards and contributing to the water crisis. Figure 1.10 schematically illustrates the main limitations of conventional wastewater management systems, while Fig. 1.11 shows a more enlightened approach to water and waste management that preserves potable water for the vital processes that require it, while constructively managing the waste process to preserve the quality of the water resource.

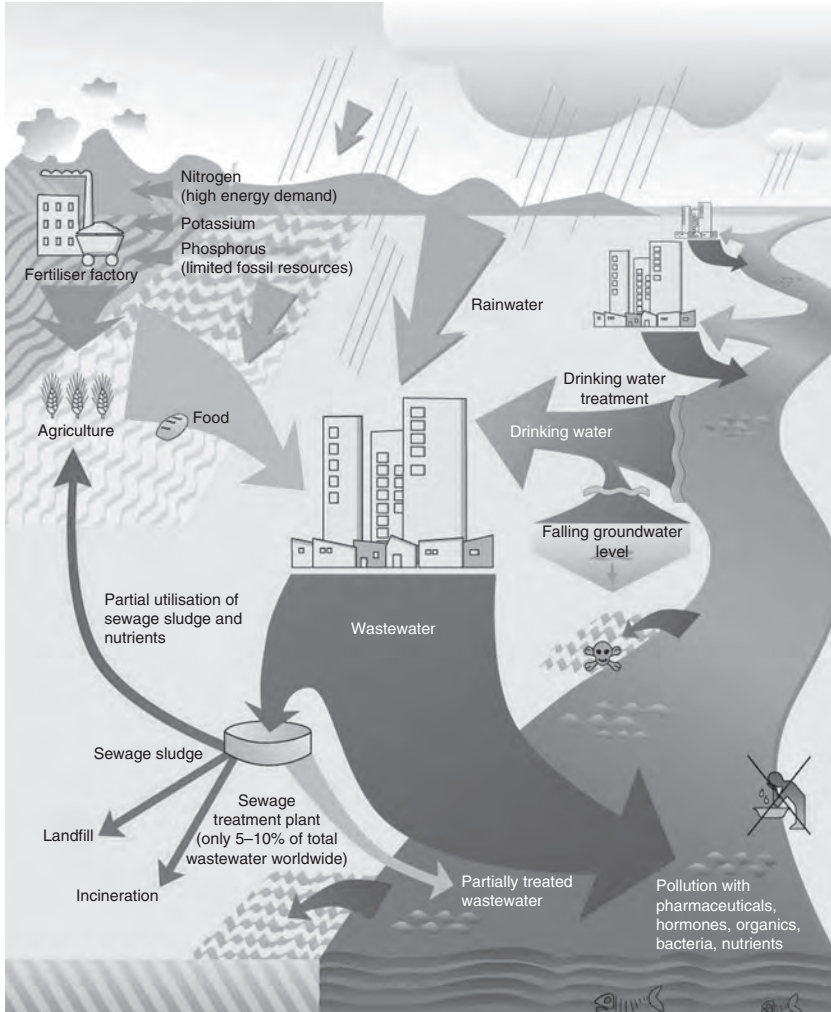


FIGURE 1.10 Existing water and wastewater stream: The conventional treatment of water requires chemicals and energy to generate potable water, then it adds contamination back into the water resource after use.

As a population increases, there is a greater demand for water. There is also increased pollution, which further depletes the available water. Because of water shortages and wastewater treatment plant overflows into waterways, the availability of clean water is decreasing. The new technologies that require chemically treated, high-pressure water to produce natural gas promise to further increase the stress on our water supplies. As the availability of clean, potable water resources becomes more limited, finding alternative sources for water and improved ways to manage our waste will become all-important.

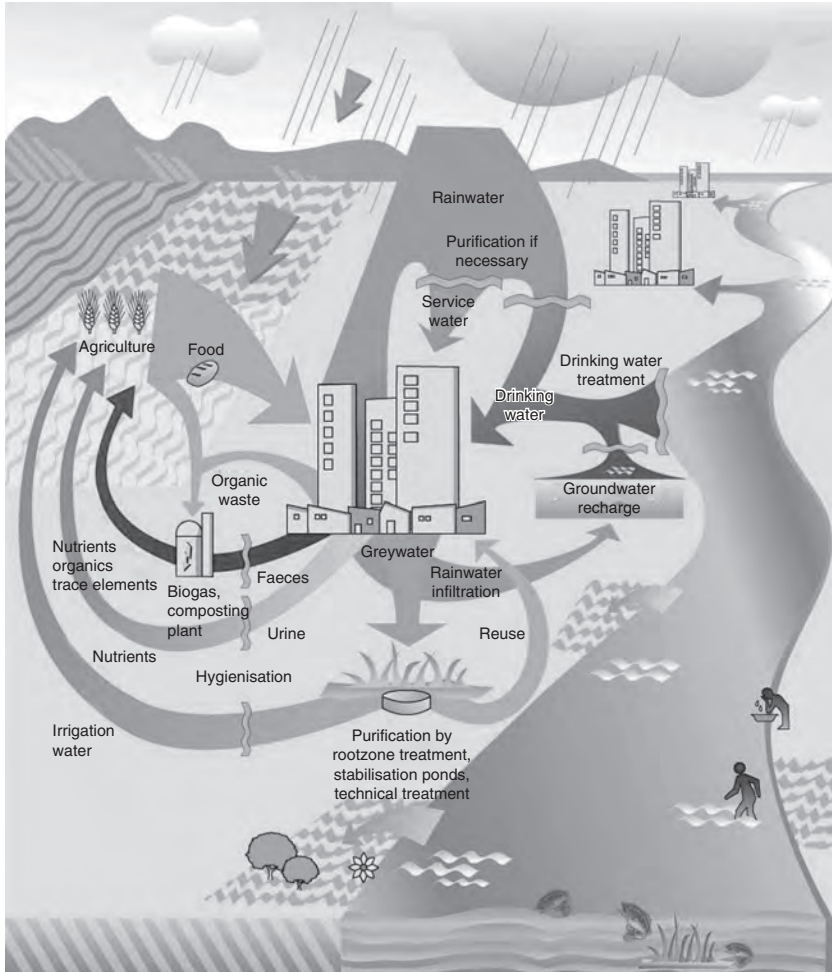


FIGURE 1.11 Optimal water and wastewater stream: A more enlightened water and waste management uses the waste constructively rather than contributing to the pollution of the water resource.

Alternative Waste Management

World Health Organization (WHO) defines *sanitation* as a group of methods to collect human excreta and urine, along with other community waste, in a hygienic way to maintain community health. Western plumbing systems are commonly water-based systems that use drinking-quality water to carry waste away to be addressed elsewhere. “Elsewhere” is presumed to be a septic field or a sewage treatment plant. Older cities have sewer systems that combine waste

and storm water in the same pipe. When rainstorms occur that overwhelm the retention capacity of the sewage treatment plant, the combined storm water and sewage overflow into the local river or stream. This waterway might be someone's water source downstream. So an argument can be made that the typical western sewer system doesn't actually treat the problem as much as move the problem downstream to become someone else's problem.

Rural and suburban communities are confronted with problems that are unique to their size and population density, and are often unable to superimpose solutions typically applicable to larger urban areas. A good example of such a problem can be found in wastewater services.

In the past, priorities for water pollution control focused on the cities, since waste generation from these areas was most evident. In such high-density areas, the traditional sanitary engineering approach was to construct a network of sewers to convey wastewater to a central location for treatment and disposal to surface waters. Since a large number of users existed per unit length of sewer line, the costs of construction and operation could be divided among many people, thus keeping the financial burden on each user relatively low.

Within the past several decades, migration of the population from cities to suburban and rural areas has been significant. With this shift came the problems of providing utility services to the residents. Unfortunately, in many cases, solutions to wastewater problems in urban areas have been applied to rural communities. With the advent of federal programs that provide grants for construction of wastewater facilities, sewers and centralized treatment plants were constructed in these low-density rural settings. In many cases, the cost of operating and maintaining such facilities imposes severe economic burdens on the communities.

Although wastewater treatment and disposal systems serving single homes have been used for many years, they have often been considered an inadequate or temporary solution until sewers could be constructed. However, research has demonstrated that such systems, if constructed and maintained properly, can provide a reliable and efficient means of wastewater treatment and disposal at relatively low cost.

The following chapters provide technical information on alternative on-site wastewater treatment and disposal systems. They do not contain standards nor do they contain rules or regulations pertaining to on-site systems. The methods proposed herein aim to manage excreta and chemical waste in ways that serve to protect the water supply, and by so doing, reduce the causes of disease.⁸ They also serve to address waste management at the source in an environmentally efficient manner without polluting the watershed.

The systems discussed include the following:

- Aquatic plants
- Constructed wetlands
- Biological filters
- On-site blackwater systems
- Septic fields
- Latrines and privies
- Composting toilets

Conclusion

The objective of this book is to illustrate alternative sources of water and means of waste disposal such that water quality will be preserved and the nutrients in our wastewater will be constructively reused. The presentation of innovative concepts being researched and developed from international sources is the topic being presented herein. The intended audience for this information includes those involved in the design, construction, operation, maintenance, and regulation of on-site wastewater systems and those that are concerned about preserving a vital resource for future generations.

Notes and References

1. *Global Water Supply and Sanitation Assessment 2000 Report*, WHO, UNICEF, 2000 (accessed May 2, 2005). www.who.int/water_sanitation_health/monitoring/jmp2000.pdf
2. *Meeting the Millennium Development Goals Drinking Water and Sanitation Target. A Mid-Term Assessment of Progress*, WHO, UNICEF (accessed June 15, 2005). www.who.int/water_sanitation_health/monitoring/jmp04.pdf
3. Quinn, A., "U.S. Intelligence Sees Global Water Conflict Risks Rising," Reuters, March 22, 2012.
4. Credit: Howard Perlman, USGS; globe illustration by Jack Cook, Woods Hole Oceanographic Institution (©); Adam Nieman. Data source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, *Water in Crisis: A Guide to the World's Fresh Water Resources* (Oxford University Press, New York).
5. The United States leads the world in water consumption at 150 gallons per person per day. Looking forward, this is not a sustainable number, given the projected water shortages for a significant part of the country. Therefore, the United States, along with the other parts of the world, should have a strong interest in better management of the available freshwater supply.
6. Prater, A. M., *Depletion of the Ogallala Aquifer*, April 23, 2010, www.helium.com/items/1812428-ogallala-aquifer-depletion.
7. *Gale Encyclopedia of Public Health: Sanitation*.
8. *Technology for Water Supply and Sanitation in Developing Countries*, WHO, Geneva, 1987.
9. *Injury and Illness Prevention Program, Appendix 1, Glossary of Terms*, San Diego State University (accessed April 17, 2005).



This important chapter is representative of the authoritative content available on McGraw-Hill Education's **AccessEngineering**, the award-winning engineering reference tool for professionals, academics, and students. It provides fully searchable text optimized for the web with exclusive, faculty-created, how-to videos, curriculum maps tied to core content, plus calculators, interactive graphs, and downloadable tables.

For information regarding trial access, pricing, or placing an order, please contact us at:

Email: stsales@mhprofessional.com

Telephone: 1.877.840.2297 (US)

1.614.759.3663 (Outside the US)

