Drinking Water

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Key Concepts

- Preventing water-borne disease is necessary to maintain good health.
- Protecting water sources is key to providing safe water supplies.
- Keeping wastewater discharges away from water supplies is crucial to water quality protection.
- A host of chemical, biological, and physical agents from diverse sources can adversely affect water quality.
- There is little regulatory control over individual water supplies in rural areas, except for during well development and property transfer.
- People may not be aware that no one is protecting the quality of their personal water supply.
- Local department programs typically include well siting, inspection, and permitting; education may be another important activity.
- Municipal water supplies have comprehensive regulatory controls beyond the direct purview of the local health department.
- Local health departments have a community role in protecting municipal water supplies.
- Outbreaks of water-borne disease can happen in virtually any system.
- Investigation of water-borne disease outbreaks is part of a local health department's responsibility.
- Emergency situations, including bioterrorism, may require local health departments to assume a leadership role.

Do We Have a Problem?

The United States long ago adopted a view that anyone, anywhere in the country, should expect safe clean water from any tap. Indeed, the Safe Drinking Water Act of 1974 has resulted in a comprehensive system of federal and state controls governing municipal water supplies. Private supplies, however, largely remain under the purview of local officials. Recent events suggest that although our drinking water usually is safe, serious problems may still emerge in both rural and urban settings.

Albany, New York, September 1999

Visiting the county fair turned into a life-threatening experience for hundreds of people near Albany, New York. An infectious strain of *E. coli* bacteria washed into the groundwater from a local barn. The fair got its drinking water from local wells, so the contamination spread quickly to those thirsty people using the local supply. More than 600 people were known to be infected. At least 58 people were hospitalized with bloody diarrhea, abdominal cramping, and fevers. At least two deaths were attributed to kidney failure caused by the bacteria; a 79-year-old man and a 3-year-old girl died from doing nothing more than having a drink of water.

Milwaukee, Wisconsin, April 1993

Watery diarrhea, abdominal cramping, fever, and nausea ravaged the population of Milwaukee, Wisconsin. Approximately 400,000 individuals were affected, with hundreds hospitalized and several immunocompromised victims dying. Drug stores and supermarket shelves were emptied of anti-diarrheal medicines. Too widespread an outbreak to be food-borne, the problem could only have been in the water supply. Yet, standard bacterial tests indicated no signs of problems, and water treatment plants were meeting performance standards. It took approximately one week to discover that the cause of this outbreak was a protozoan parasite, *Cryptosporidium*, coming through one of Milwaukee's major water treatment plants.

These two incidents teach us many things, but two of the most important lessons are that rural settings present special problems of contamination because they lack substantial protection from regulatory controls. The other lesson is that municipal settings, even though protected by comprehensive treatment and other regulatory requirements, can still present unreasonable risks to a community.

Local health departments often provide the first (and usually only) line of defense in protecting the drinking water quality of rural areas. Although city dwellers have other agencies protecting their water quality, they may turn to the local health department for answers about the risk from their water and in response to disease that may originate, or may be perceived of as originating, from their taps. Health departments need to be prepared to respond to these questions independent of regulatory authority.

Drinking Water Contaminants

Water can have biological, chemical, and physical contaminants. Some contaminants result in acute (or immediate) effects; others present a threat only following chronic (or long-term) exposure. Table 1 gives a summary of typical sources of the most important contaminants. It is vital when evaluating the potential for water contamination to consider the source! For example, groundwater ordinarily doesn't have to be checked for sediments because solids can't get into the **aquifer** (underlying layer saturated with water). Similarly, radon gas can be a problem only in groundwater because it quickly evaporates out of any surface water.

TABLE 1
Key Drinking Water Contaminants

Type	Example	Typical sources
Biological		
Bacteria	E. Coli	Water in contact with wastewater
Viruses	Hepatitis A	Water in contact with wastewater
Protozoan	Giardia & Cryptosporidium	Normal surface water inhabitant
Parasites	Parasitic worms	Fecal contaminated water (typically tropical diseases)
Chemical		
Nitrogen	Nitrate	Fertilizer
Metals	Lead	Home plumbing
Chlorination byproducts	Trihalomethanes (THMs)	Chlorination
Pesticides	Atrazine	Agriculture
Taste and odor producers	Hydrogen sulfide	Groundwater
Salt	Road deicing salt	Cold climate locations
Physical		
Solids	Sediments from erosion	Agriculture
Radiation	Radon	Underlying rock

Many contaminants are too difficult and expensive to evaluate routinely, so indicators are used. Of particular note is the use of **coliform bacteria** to measure possible contamination of water with wastewater or other fecal sources. Coliform bacteria are not (generally) harmful themselves, but they are indicators of pollution from organic sources containing pathogens. The total amount of material in water can be easily measured through testing for **suspended solids**, **dissolved solids**, and **turbidity**. These measures are not specific for the individual constituents of water, but they are useful measures of the magnitude of the material in the water. It is important to remember that good quality water has material in it—evaluating the nature and concentration of that material is key to determining water quality.

Sources of Contamination

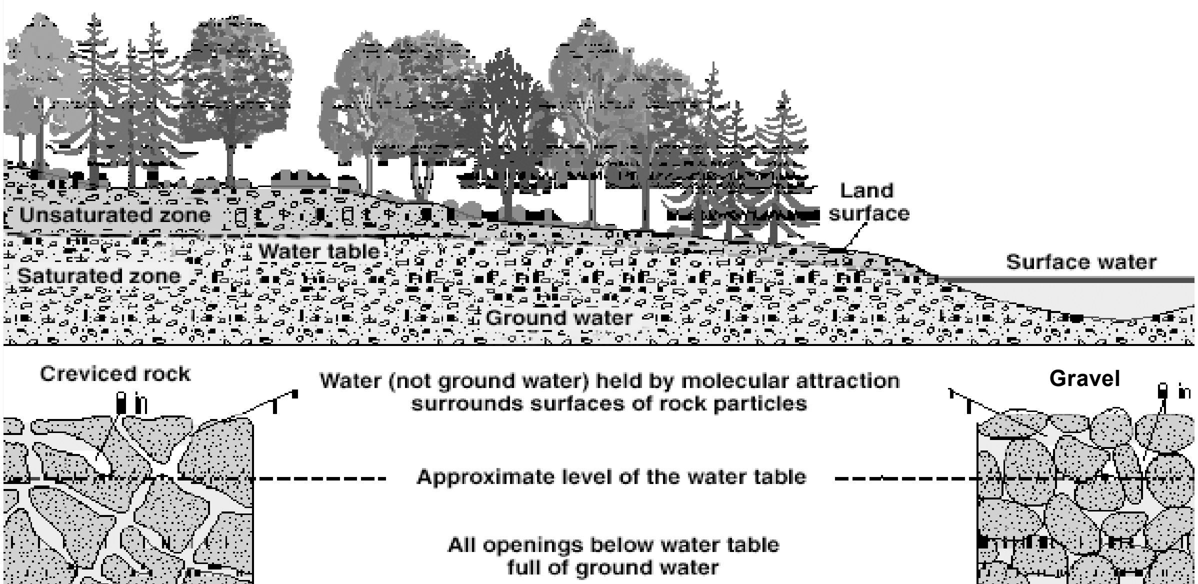

FIGURE 1. Groundwater Aquifer

Groundwater

About half of the water used for drinking in the United States is groundwater. Groundwater is underground or subsurface water. Groundwater comes from surface water percolating through overlying soils and it resides in the pore spaces between particles of soil and other geologic materials. Formations that have all the pore spaced saturated with water are called saturated zones or **aquifers**. The top of the aquifer is called the water table. Figure 1 shows how groundwater is located in an underground, saturated zone but can intercept surface water. Water wells extend into aquifers to allow water to be collected and pumped to the surface. Groundwater does not (generally) exist as underground rivers or pools – instead it is captured between particles above an impermeable layer that restricts water movement further downward.

As surface water percolates downward, sediment loads (including microscopic bacteria, viruses and protozoa) generally are filtered out. However, all troublesome sediments may not be captured if the aquifer is very shallow. For example, a farm may have an animal feedlot that hosts a multitude of pathogens on the surface. If the aquifer is too close to that pollution source, bacteria may be insufficiently filtered by the soil and move into a neighboring well.

Other primary sources of groundwater contamination are pollutants discharging directly into the ground. The rural environment provides another excellent example. Many homes in the country are not connected to wastewater treatment plants. These homes often dispose of their wastewater through the use of on-site treatment. If the wastewater comes into contact with the aquifer, pathogens and other pollutants in the wastewater can be transferred into the water supply. A critical need in providing safe drinking water is to separate its source from any contamination with wastewater.

Chemical contamination also is a threat to groundwater through direct discharge. Flammable liquids, such as solvents used for industrial cleaning, are often stored in underground tanks. Leaking of these materials has been a major problem throughout the United States, often polluting aquifers used by major population centers (including areas in Long Island and Los Angeles).

Surface Water

Municipal areas draw heavily on surface water for their drinking water supplies. Surface water sources—lakes, reservoirs, and rivers—are not (with a few exceptions) suitable for drinking without treatment. Good quality surface water supports life, but we don't want "life" in our water glasses. Again, keeping sources of contamination, such as wastewater, away from surface water is critical to controlling the safety of the water supply.

Surface water treatment is complex and largely done at the municipal level. Relatively few individuals directly use surface water from personal sources, such as a local pond or a roof-top collection system. However, those that do must be careful in removing and destroying contaminants that occur in these systems. Local surface water supplies are not protected by federal and state government regulation, so contamination may go undetected until it results in a major adverse health effect.

Water Treatment

Somewhat paradoxically, municipal treatment of water almost always includes adding a chemical that is quite toxic! This chemical is chlorine, and its intention is to destroy disease-causing microbes in the water. Chlorine is excellent in accomplishing this goal, and the United States rarely faces water-borne disease outbreaks. However, treatment includes maintaining low levels of chlorine in the water to prevent survival of pathogens anywhere in the treatment and water delivery system. This means that trace levels of this chemical are delivered to the municipal taps. In addition to concerns about the chlorine, byproducts of chlorination are formed. Such byproducts include chloroform, one of a group called **trihalomethanes** (THMs). Many of these byproducts are known or suspected to have adverse health effects, such as causing cancers. However, they are permitted in water because the benefits of chlorination in protecting against acute disease outbreaks are seen to vastly outweigh the risks of chronic disease possibly occurring from these byproducts. Nevertheless, the public may disagree with this approach to water quality management.

Individuals may take matters into their own hands and purchase bottled water or use home purification systems that remove chlorine and its byproducts. Health departments may be looked to as a source of information about this controversial issue even though they generally have no direct role in influencing municipal water treatment.

Fluoride is added to water in all municipal systems except in those communities where voters specifically voted not to fluoridate (a very tiny percentage of the population). There is no individual option as to whether there should be fluoride in the water—if no ballot issue is approved to prevent fluoridation, then all members of that community receive fluoridated water. Unquestionably, fluoride has been extraordinarily successful in preventing dental caries. However, some people are beginning to question fluoride’s safety, particularly with regard to possibly affecting the bone strength of the elderly following a lifetime of consumption. Although local health departments usually have no direct role in influencing fluoridation, they may be looked to for community leadership in providing health information concerning this treatment practice. The local health department can also provide a valuable service in educating individuals, who do not consume water from a municipal supply, about the benefits of fluoride

Home Plumbing

Another source of contamination is the home plumbing system. Historically, lead was used generously in better quality water fixtures and as solder. It is now known that lead can leach into water and present substantial problems to consumers. Although lead in water systems is now regulated, old systems have little regulation. Furthermore, older homes with lead in their water systems may also have substantial problems with old leaded paints. Although lead in paint typically is a much larger problem than lead from water supplies, the combination from both sources may be particularly troublesome.

Individuals also are at risk from **backflows**. Plumbing changes may inadvertently result in connections between wastewater and potable water lines. For example, a hose in a drain may siphon back into the drinking water line. Although building codes include safety features to prevent such occurrences, building modifications may be done with little understanding of this threat. Individuals doing their own plumbing may be particularly likely to fail to provide adequate backflow prevention. Health department programs may be of great value in educating “do-it-yourselfers” about these threats.

Similarly, contamination of drinking water can occur if water pressure is too low in a system. Water pipes tend to leak—if the water pressure is high, the water leaks out and contamination cannot migrate against that flow. If water pressure is low, a leak may result in contamination moving into the drinking water line because there is no pressure preventing this movement. For example, low pressure in a water pipe underlying a sewage leach field may result in movement of contaminants into the water supply.

Public Health Significance

Availability of a safe water supply is of paramount importance to public health. The regulatory system in the United States has been successful—with a few rare exceptions, such as the outbreak of *cryptosporidiosis* that occurred in Milwaukee—in protecting municipal systems from pathogen contamination. Adverse health effects from chronic exposure to trace contaminants in municipal water remain a controversial issue. Individuals may try to avoid this risk by turning to alternative supplies. However, nonmunicipal systems do not have comprehensive regulatory protections, so using these alternatives may increase actual health risk to the consumer. Furthermore, even bottled water, regulated by the Food and Drug Administration (FDA), has less regulatory protection than provided by the Environmental Protection Agency (USEPA) for municipal systems.

Individuals in rural areas who use local wells (or surface water supplies) have very few protections from contamination. Few people realize that, although municipal water supplies are very well regulated, there is generally little governance of non-public supplies. As people move to the country and population density increases, soils can become saturated and groundwater may be inundated with on-site sewage contamination. Alternatively, local homes too close to feedlots and other sources of animal wastes may have contaminated water supplies. In either case, local residents become vulnerable to water-borne disease and health problems such as diarrhea (which usually are not reported). It is difficult to link adverse health outcomes to a local contaminated water supply even though growing populations are using an unregulated, non-public water supply.

Responsibilities and Options Available to Local Health Departments

Often, the local health department is the principal authority responsible for individual water supplies in areas not served by municipal systems. Health department programs that provide protections to local water supplies typically include

- Assessment of site suitability,
- Specification or approval of well design,
- Specification or approval of specific well location,
- Well remediation and decontamination,
- Well water sampling, analysis, and data interpretation,

- Well closure planning and regulatory programming,
- Non-community, private water system inspection and sampling, and
- Community and individual education.

Local health departments often have formal responsibility to provide these protections through a regulatory program governing well construction during property development. Some areas also require health department checks of rural water quality as part of property transfer. To a growing extent, lenders are also requiring checks of rural water quality as part of the process of qualifying for a loan. Often, the health department will conduct the sampling, analysis, and interpretation as part of this process. Rural developments often have water wells and on-site waste treatment systems in close proximity; it is typically the charge of the local health department to ensure that the water supply is protected from contamination from the wastewater.

In addition to its formal role in helping to protect rural drinking water quality, local health departments can play a key leadership role affecting municipal supplies. If there is a water problem, or perception of a water problem, the local health department is often turned to for advice. Local health departments need to serve as part of the team that interacts with the community and provides education. For example, if disease characteristics of water-borne origins are reported in a community, the health department usually will be best positioned to identify whether a problem exists and to interact with the municipal water purveyor. Alternatively, if the municipal water system has a problem (e.g., a pipe break that potentially allows contamination of the system), the health department is well placed to help inform and educate the public about the nature, duration, and severity of the problem. The public typically will not know (or care) that municipal water quality is not an activity regulated by the health department. If the public perceives that the water presents a threat to its health, the health department will be turned to as a primary resource. Certainly response to any act of bioterrorism targeting a municipal water treatment supply would require active local health department participation. It is imperative that the health department not only meets its obligation toward protecting water in the rural setting, but also be a leader in helping the community with issues concerning municipal water quality.

Current Issues and Opportunities

The continuing importance of local health departments in helping individuals with their private systems is obvious. The potential for contamination of private systems, with serious consequences, is substantial. Although the majority of the population is using municipal supplies, a substantial number relies on local systems (see Figure 2). The local health department often provides the only external support to these systems. However, there are additional roles for the local health departments to play in trying to ensure safe drinking water for all.

Private Water Systems

The USEPA has authority governing public water systems, those systems having at least 15 service connections or serving 25 or more people for at least 60 days annually. Thus, a small private system could serve multiple families and still have no regulatory protection other than at the local level.

Sampling, Analysis, and Data Interpretation

Individuals often have concerns about their water quality and do not know where to turn for help. The local health department can effectively play a primary role in providing answers to their questions. In municipal areas, this role may largely involve directing individuals to the proper resource or referencing the annual water quality report (see listing in "Resources for Additional Information" section at the end of the chapter). In rural areas it may mean providing a convenient and inexpensive investigation service. Typically, this investigation involves sampling for coliform bacteria as an indication of possible water supply contamination. Health departments also may be able to direct consumers to other sources for more comprehensive evaluation should issues arise such as possible chemical

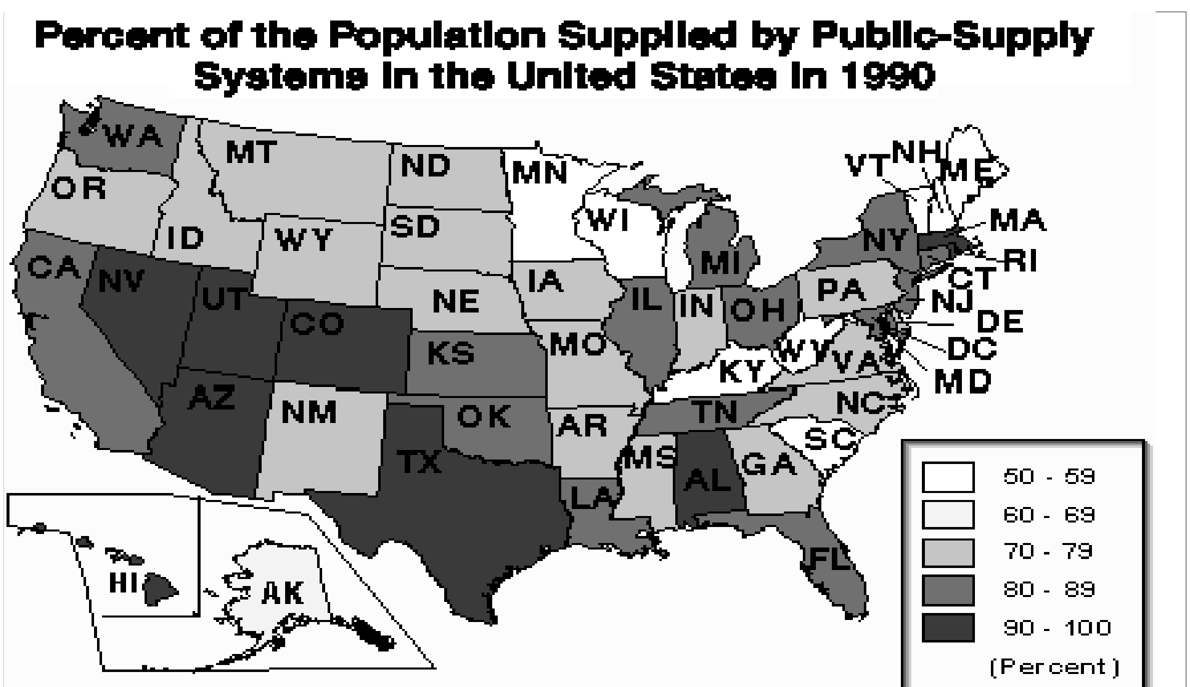

FIGURE 2. Public Supply Systems in the United States

contamination.

Education

People generally don't think about their plumbing—water comes in when you turn on the tap and water leaves through the drain. As long as this happens without change, little thought is given to possible health hazards. However, as systems age and population densities increase, existing systems may fail to deliver safe drinking water. Providing people with the knowledge to properly maintain and inspect their own systems is a critical, although not mandated, function that may be adopted by local health departments. Similarly, getting people to understand and think about how their own activities, such as how pouring used oil down a sewer can pollute their own watershed or aquifer, can be an effective tool for changing behavior and protecting water quality.

Local Planning

Providing a safe water supply to a large degree depends on protecting the source water. This may be a large groundwater aquifer, local wells, or surface water sources. The compatibility of land uses should be considered with regard to water quality. For example, a suburban housing complex that is dependent on on-site wastewater disposal and individual wells and is located on sandy soils that allow little filtration of wastewater will almost inevitably result in water quality problems. Alternatively, inappropriately abandoning wells can provide a conduit for pollution to enter aquifers without protection from filtering through the soil. Planning needs to consider the appropriateness of local systems and the need to develop or link to municipal systems.

Similarly, watershed protection needs to be provided to ensure the adequacy of surface water sources. For example, heavily developing a watershed around a drinking water reservoir is asking for trouble. (Yet, the desirability of housing around water drives up the incentive for developing such land!) The use of **Geographic Information Systems** (**GIS**) to produce computer-generated maps linking land, demographic, and health features of a region shows particular promise as a planning tool. Local health departments can contribute to and use such tools in making community decisions that have long-term implications on water quality.

The cumulative impact of many small sources of contamination to a surface water or to a groundwater source is seldom considered by the individual polluter. For example, someone spreading lawn fertilizer may logically conclude that the relatively small amount of material being added to a watershed is negligible compared to the overall amount of nutrient addition. However, it is the entire community sharing these kinds of thoughts that will result in many small inputs that lead to excessive loading and substantial resource degradation. Planning can take into account typical human behavior and control development and activities to provide necessary environmental protections.

Conclusions

Local boards of health must make important decisions in protecting their communities' drinking water quality. Most obvious is the need to ensure that their local health departments meet the needs of the rural areas that do not have protections associated with being part of municipal systems. As populations increase and more people use nonmunicipal (private) systems, this role will increase in scope and importance. Yet, the regulatory role remains small, and education and other innovative health department programs must take priority in ensuring the protection of the rural drinking water supply. Alternatively, municipal drinking water has comprehensive regulatory protection from agencies other than local health departments. However, as the key local health agency, health departments need to be involved in issues affecting the water supply, such as planning, emergency response, and education. There must be recognition that having a safe water supply is a basic necessity in maintaining good health. Again, it is the responsibility of the board of health to ensure that its department takes an active and comprehensive leadership role reflecting the characteristics of the community and its associated needs to guarantee the continual supply of safe drinking water.

Resources for Additional Information

American Water Works Association. <www.awwa.org>.

Barzilay, Joshua I. 1999. *The water we drink: Water quality and its effects of health.* New Brunswick, N.J.: Rutgers University Press.

Consumer Confidence Reports. <www.epa.gov/safewater/ccr1.html>.

Spellman, Frank R. 2000. *Drinking water handbook.* Lancaster, Pa.: Technomic Publishing.

United States Environmental Protection Agency. Office of Ground Water and Drinking Water. <www.epa.gov/safewater/>.

Water Quality Association, *Water quality glossary*. <www.wqa.org/glossary.cfm>.

Wastewater

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Key Concepts

- Wastewater may contain microbiological disease agents (pathogens), chemical poisons (toxins), and/or other biological, chemical, and physical components that may disturb natural aquatic ecosystems.
- The public may be exposed to wastewater pathogens and toxins through several routes, including drinking water (ingestion), swimming (dermal exposure), or breathing (inhalation).
- Wastewater source reduction and proper treatment prior to discharge into the environment can reduce risks associated with contaminants to acceptable levels.
- Twenty-five to 35% of wastewater currently generated and up to 40% of new construction wastewater is discharged to residential on-site (decentralized) wastewater treatment systems.
- Increasing construction in suburban, nonsewered areas has resulted in increased on-site wastewater volume generation and associated public health risks.
- Proper siting of on-site wastewater treatment systems is crucial to protecting groundwater and surface water quality.
- Cumulative effects of many small wastewater treatment systems can have large effects on an area's water resources.
- Local health departments have the primary responsibility for enforcement of regulations related to on-site wastewater treatment systems.
- Local public health departments must be prepared to respond to complaints associated with wastewater discharged to municipal and small commercial wastewater treatment systems (publicly owned treatment works [POTWs]) or directly into the environment without treatment.
- Local public health departments and boards of health have a responsibility to take a proactive role in addressing wastewater generation, treatment, and disposal issues to prevent associated problems.
- Proactive activities to prevent adverse impacts from on-site wastewater disposal often include health department involvement in local planning activities.

Public and Environmental Health Significance of Wastewater Management

What Is Wastewater and Where Is It Generated?

Wastewater may be defined as "water that has served its original purpose and is intended for treatment and/or disposal." Wastewater may be generated from discrete **point sources** (Figure 1), such as industrial wastes, or diverse **nonpoint sources**, such as agricultural or urban runoff. Primary water uses that generate wastewater include drinking, washing, solid and liquid waste processing, cooling, and irrigation. Major sources of wastewater include residential, industrial, and agricultural sources (Figure 2). Primary wastewater contaminants of public health concern are microbiological disease agents (**pathogens**) and chemical poisons (**toxins**). Other biological, chemical, and physical wastewater contaminants may also disrupt natural aquatic systems (e.g., siltation of rivers and streams due to erosion). About 65% to 75% of domestic wastewater is discharged to a centralized municipal wastewater treatment facility or POTWs. Most of the remaining wastewater is discharged to a **decentralized** on-site wastewater treatment system. Up to 40% of new construction depends on decentralized on-site wastewater treatment systems. A small amount of residential wastewater generated is discharged to lakes, rivers, streams, or soil-groundwater systems without any treatment.

Levels of contaminants in wastewater may be determined directly. However, it is often quicker and more economical to test *indirectly* for indicators of contamination. For example, **coliform** is a group of bacteria used to indicate water contamination. *Total* coliform includes the subgroup **fecal** coliform and other bacteria that may indicate water contamination. The fecal coliform group excludes some nonfecal coliform bacteria and is often used to measure surface water or groundwater contamination from

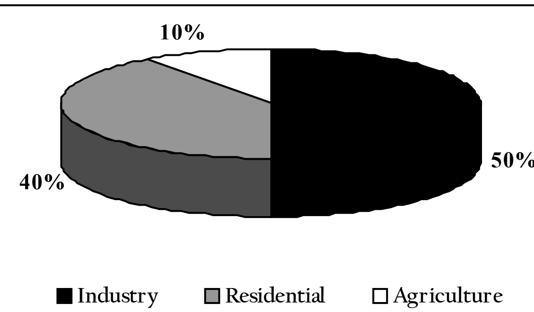

FIGURE 2. Approximate Relative Volumes of Wastewater, Based in Primary Water Use Sectors in the United States

sewage. *Escherichia coli* have been suggested as an even more specific indicator of human fecal contamination of water.

Wastewater management usually focuses on treatment and disposal. However, water use reduction may be of greater management potential. Almost all of the water that is used by a home, business, or industry is discharged as wastewater, except for a small amount that evaporates. Therefore, decreased water usage reduces wastewater generation. Examples of water use reduction technology include low-flush toilets, low-flow showerheads, and modified industrial processes. Innovative local health departments should work toward reducing wastewater generation through promoting water use reduction. Local planning and utility agencies should also be included in these efforts.

History of Wastewater Generation, Treatment, and Disposal

Throughout most of human history, wastewater has been discarded into lakes, rivers, and streams or onto the ground. Prior to urbanization and the resulting increased population density, wastewater contamination was more limited in scope and distribution. Natural environmental systems often had the ability to absorb and treat this wastewater (**assimilatory capacity**) relatively quickly to limit public health and environmental concerns. However, when humans began to use water as a carrier for human wastes (feces and urine) and industrial wastes, hazards associated with untreated wastewater disposal increased dramatically. Development of the flush toilet decreased local risks of infectious disease transmission through wastewater but also led to increased wastewater production. With increased production has come the need for increased numbers of POTWs and on-site wastewater treatment systems.

In 1972, the **Clean Water Act** (**CWA**) was passed in response to national water quality concerns. The **National Pollution Discharge Elimination System** (**NPDES**) was developed to regulate the discharge of wastewater into surface water by implementing a national permitting system. Municipal wastewater treatment is primarily the responsibility of the federal and state governments; however, state agencies and local public health departments usually are responsible for developing and enforcing regulations associated with on-site wastewater disposal systems. Although significant improvements have been made in national water quality as a result of the CWA and related regulations, many problems remain from discharge of improperly treated or untreated wastewater into the environment. Public education concerning wastewater contaminants, environmental implications, and methods to reduce associated risks is essential to protect public health and the environment.

Assimilatory Capacity of Natural Aquatic Systems

Natural aquatic systems have the assimilatory capacity to deal with some wastes without serious negative environmental effects. Water contains **dissolved oxygen** (**DO**) that is used by aquatic organisms during respiration. Aquatic DO concentrations are reduced by oxygen-demanding wastes during the process of microbial **biodegradation**. **Eutrophication** is a natural aging process that occurs in many bodies of water, resulting in decreased DO and siltation. However, cultural (or human) practices may cause *cultural* eutrophication, leading to an imbalance in aquatic systems, algae blooms, and changes in natural aquatic organism populations to more pollution-tolerant species. **Biochemical oxygen demand** (**BOD**) is an indicator of *organic load*, or the ability of wastes to deplete DO in an aquatic system. Chemical and physical properties of wastes can also alter **pH**, poison aquatic animals or plants, make it difficult for organisms to respire or photosynthesize, or change the ability of the water to retain DO (e.g., increased water temperature due to thermal pollution). For example, if a waste high in organic matter is discharged to a stream with insufficient assimilatory capacity to absorb and treat this level of wastes, DO may be depleted, potentially resulting in fish kills and aesthetic concerns such as poor appearance and odor.

Routes and Magnitude of Wastewater Contaminant Exposure

Humans can be exposed to wastewater contaminants through several routes, including drinking (**ingestion**), swimming or bathing (**dermal** exposure or skin contact), and breathing **aerosols** (**inhalation**). These exposures may potentially result in adverse health effects, primarily from microbial and chemical contaminants. Drinking untreated water from a well, lake, or stream contaminated with wastewater may transfer infectious agents such as bacteria, viruses, and protozoa, or chemical poisons such as metals, solvents, or pesticides. Ingestion is the exposure route that generally has the highest risk for causing illness because contaminants gain direct access to the body. Some chemical toxins and pathogenic microorganisms may be transmitted through inhalation of aerosols (suspension of tiny water droplets in air). Usually the least hazardous route of exposure is direct skin contact during bathing or swimming. Unless there are open sores to allow pathogenic bacteria or chemical irritants to enter body tissues or bathing water is accidentally swallowed, water contaminants are usually not present in high enough concentrations to present a significant risk of illness through dermal exposure.

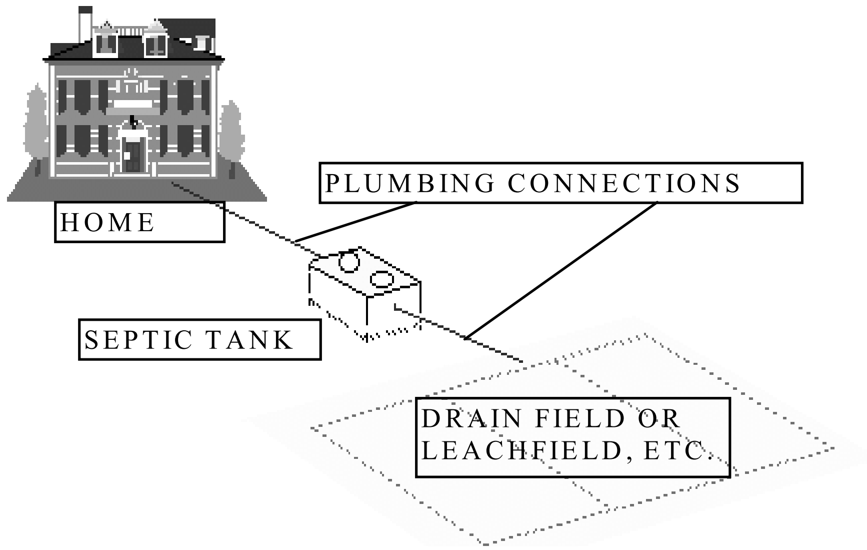

FIGURE 3. On-site Wastewater Treatment System Components (courtesy Nadakavukaren, 1996)

On-site Wastewater Generation, Treatment, and Disposal

System components. On-site wastewater treatment systems are referred to by several names, including *septic, small-waterborne, decentralized,* and *private sewage disposal systems*. However, many on-site systems have components in common, such as (1) a **septic tank** or other solids settling and storage devices (Figures 3 and 4), (2) a **leachfield** (*drain field*) or other *subsurface seepage system* (Figure 3), and (3) *plumbing connections* that link the components of the system (Figure 3).

The septic tank provides for initial treatment by allowing solids to settle out and for scum to rise to the top. There is also some **anaerobic** (without oxygen) biodegradation of organic wastes. Most commonly, wastewater exiting from a septic tank drains into a leachfield. This is a subsurface area through which the wastewater slowly drains, allowing the wastewater pollutants to be filtered out and/or decomposed.

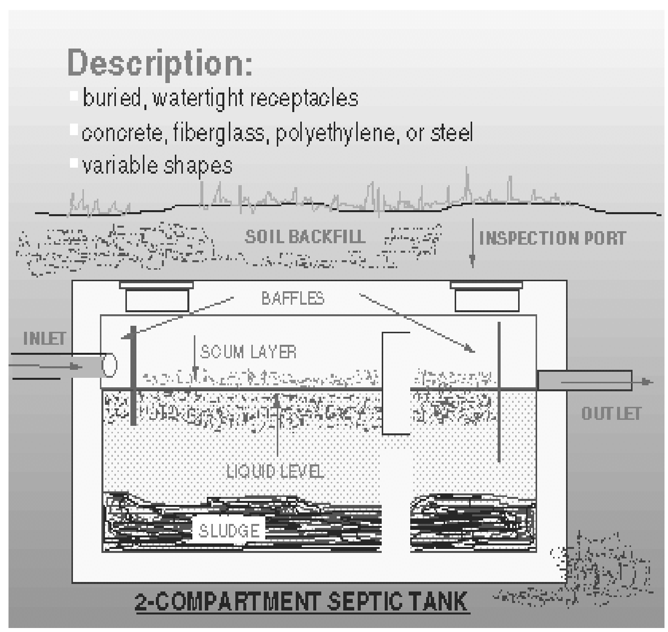

FIGURE 4. Septic Tank Design (courtesy Nadakavukaren, 1996)

Elevation and separation distances for septic tanks and other treatment system components (e.g., subsurface seepage systems) need to be adequate to ensure prevention of cross-contamination of drinking water wells. Wells should always be higher in elevation than wastewater system components to limit well contamination risks due to groundwater migration. Care must also be taken to ensure that wastewater is adequately separated from groundwater, including groundwater that seasonally may be perched just under the ground surface. Other important considerations include proper slopes to ensure sufficient movement of **effluent** (wastewater outflow) from the home to the treatment system components, design and placement of the subsurface seepage system to prevent soil saturation, and proper effluent **disinfection** before discharge. Another critical component of evaluating a site for on-site wastewater disposal is the landscape position of the site. Sites with steep slopes must be avoided as well as poorly drained sites such as flood plains. On-site wastewater treatment system designs should be evaluated to determine if they can adequately treat wastewater generated without causing significant public health and aesthetic concerns.

The ability of soils to allow movement of wastewater through soil pore spaces (**permeability**) into soils as soil moisture (**infiltration**) and movement through soils into groundwater (**percolation**) are critical for proper wastewater effluent treatment. A moderate rate of infiltration and percolation allows for reduction of pathogens and other wastewater contaminants through natural biological, chemical, and physical processes. Soil permeability can be determined by a soil evaluation. Soil evaluations for on-site wastewater treatment systems may be conducted by soil scientists or environmental health professionals, depending on state and local ordinances. A soil evaluation may include soil color determination (to evaluate soil drainage), soil structure, texture, depth to water table or restrictive horizons (shallow rock or massive clay layers), or other tests that are required by regulation or local environmental conditions. While a soil scientist may provide the most accurate evaluation of soil components, the most important factor is an accurate determination of the wastewater infiltration and percolation rate. Acceptable soils for an on-site wastewater treatment system should contain *sand, clay, silt,* and *loam* (containing *humus* or organic matter) in appropriate relative concentrations to allow for both physical filtration and **aerobic** (with oxygen) biodegradation of wastewater contaminants.

Some of the more common types of on-site septic systems are summarized in Table 1. The use of many of these systems is controversial. If ideally sited, constructed, and operated, all may work quite well. However, it is often extremely difficult to ensure that all proper conditions are met and maintained. Many systems that depend on extensive maintenance fail. It is vital for local officials to know what works in their community, and for the board of health to ensure that past practices are evaluated to determine their adequacy in protecting water quality and public health.

TABLE 1
Common On-site Wastewater Treatment Systems

System type	Media	Comments
Gravel	Gravel and surrounding soil, protected by cover of filter material to prevent media clogging	Common, economical system, but requires proper soil infiltration characteristics
Gravelless	Surrounding soil, with effluent distributed by engineered system	Engineered system types vary (often proprietary)
Sand filter	Sand, with upper influent distribution and lower effluent collection and discharge	Outflow (effluent) may require disinfection prior to surface water discharge
Aerobic treatment plant (ATP)	Surface area supports bacterial (*biofilm*) growth and biological treatment as inflow (*influent*) passes through	Effluent may require further treatment prior to discharge (often proprietary)
Mound	Coarse sand and topsoil layered above ground level with grass cover layer	Used for sites where soil factors are very limiting (low soil permeability or high water table)
Built up	Sand, gravel, and/or soil layered above and below ground level	Used for sites where soil factors are also limited
Serial distribution	Effluent discharge laterals are installed at different levels perpendicular to terrain slope	Design and installation must be proper to ensure even effluent distribution
Drip irrigation	Effluent is slowly discharged, often through intermittent dosing	Proper soil infiltrative capacity important (relatively new technology, often proprietary)
Pressure distribution	Low pressure pipe systems	Can be used in shallow soils; they work effectively because the entire system is periodically "dosed" allowing time for soil to absorb wastewater

Boards of health should also recognize that some sites are simply not suitable for septic systems and that they may face considerable pressure from developers or others to permit the construction of septic systems on unsuitable land. Local health officials need to inform their board of health of state regulations or local ordinances regarding the placement of systems, the state's or county's process for appealing denied requests, and the long-term public health implications of permitting septic systems on inappropriate sites. Through this information, boards of health will be better prepared to evaluate and respond to controversial requests, as well as any political pressure they may receive, and they can refer those who are denied a permit to the appeals system. Boards should also be aware that distraught homeowners who develop failing septic systems may file litigation against local governments, including health officials and boards of health, for not enforcing and administering laws, rules and regulations pertaining to on-site wastewater disposal.

Some state or local ordinances may allow for on-site separation of wastewater generated from toilets, containing feces and urine (**black water**), from that generated from washing (**gray water**). Gray water should present less of a public health concern because of its decreased risk of pathogen contamination. Therefore, it may be separated from black water and used as a source of water for purposes for which lower quality water is acceptable, such as irrigation. Plumbing systems may be designed to separate and store gray water in tanks or cisterns for future use, similar to rainwater collection systems. However, there is some increased risk associated with gray water use because accidental cross-contamination of gray water and black water is possible, which may lead to physical, chemical, and/or microbial water contamination. Therefore, some state or local ordinances prohibit gray water systems. If permitted, gray water systems should be designed and evaluated to limit risk of drinking water cross-contamination.

*Monitoring and maintenance of on-site wastewater treatment systems***.** On-site wastewater treatment systems must be monitored and maintained on a regular basis by a qualified, trained professional to ensure proper functioning over the life of the system. Septic tanks should be monitored regularly (every six months to yearly) and pumped to remove sludge (ideally every three to five years). However, homeowners may delay monitoring and maintenance until a problem occurs, sometimes for decades. Pumped septage sludge should be disposed of properly. Usually, this involves discharge to a POTW at a charge to the pumper. Sometimes pumped sludge must be evaluated to ensure that it does not contain contaminants harmful to municipal treatment systems.

Because of increased suburban residential construction and increased population density, it is more important than ever that on-site wastewater treatment systems be sited, designed, monitored, maintained, and permitted properly. These issues are becoming a major responsibility for state and local health departments. In rural areas, on-site treatment system management can be one of the local health department's largest programs.

Municipal Wastewater

There are two primary types of municipal wastewater that are collected using sewer systems. (1) **General wastewater** is generated from residential homes, businesses, and industry from toilets, sinks, showers, baths, washing machines, and so forth. (2) **Storm water** is generated primarily from precipitation runoff from streets, parking lots, and other surfaces. In the past, **combined sewers** collected both general wastewater and stormwater runoff. This practice has been discouraged because wastewater treatment plants cannot be sized large enough to handle sudden influxes of rainwater while retaining the capability to handle the normal flow of wastewater received during dry periods. Modern systems have **separated sewers** for general wastewater and stormwater runoff.

Some combined systems may be modified to capture stormwater and store it during periods of excessive precipitation. Following a storm, the stormwater may be released more slowly into the sewers at a rate that will not exceed the treatment capacity of the POTW. However, if the storm volume exceeds the treatment and storage capacity of the combined system, combined sewer overflows (CSOs) may be discharged to surface water or groundwater recharge areas. Efforts are being made throughout the country to minimize such releases.

General wastewater is usually of much greater environmental health concern than stormwater because of its human fecal waste component and the associated increased risk for infectious disease transfer. Application of proven treatment technologies at POTWs is necessary to reduce municipal wastewater contaminants prior to discharge into the environment. Industrial wastewater may contain other contaminants such as metals, detergents, acids, or bases, and may therefore require pretreatment prior to discharge to POTWs or the environment. Other related aesthetic wastewater concerns are odor and unsightliness.

Stormwater is ordinarily much more diluted than general wastewater, but it may contain contaminants of concern to public health and the environment. Roads and parking lots are subject to spills of oil, gasoline, antifreeze, and other potentially toxic fluids from automobiles, as well as road salts. These and other contaminants can be carried by stormwater runoff into combined sewer systems and to the local wastewater treatment facility or groundwater recharge area. Usually, initial stormwater runoff is higher in these contaminants than subsequent stormwater runoff.

*Municipal wastewater regulations***.** General wastewater contains biological, chemical, and physical contaminants that should be reduced prior to discharge into the environment. Contaminant characteristics of municipal wastewater are usually fairly consistent and can therefore be characterized within a relatively small range of indicator values. Concentration reduction of municipal wastewater contaminants is important to meet NPDES permit requirements and protect the environment and public health.

NPDES permit standards vary with the characteristics of the receiving watercourse. If sewage is to be discharged into a large river, there will be a higher degree of dilution and dispersion of the effluent than if it is discharged into a small stream, so the standards are often less stringent. Final NPDES standards are often a result of negotiations between the Environmental Protection Agency (USEPA) and a sanitary district. The types of parameters included in the final permit may also vary with the district, but often include biochemical oxygen demand (BOD), **total suspended solids (TSS),** pH**, ammonia**, and fecal coliform bacteria (Table 2).

TABLE 2
Typical NPDES Permit Parameters and Typical Maximum Levels

NPDES permit parameters	Typical contaminant levels (vary with receiving watercourse)
Biochemical oxygen demand (BOD)	Less than 30 milligrams per liter (mg/L)
Total suspended solids (TSS)	Less than 30 milligrams per liter (mg/L)
pH (0–14 logarithmic scale)	6.0–9.0
Fecal coliform bacteria	Less than 400 colony-forming units per 100-milliliter water sample (CFU/100 ml)
Ammonia	Variable

Responsibilities and Options

To effectively limit wastewater contaminants and communicate risks associated with wastewater contamination, environmental health professionals need comprehensive education and training. Preparation must include the study and application of multidisciplinary and interdisciplinary concepts (e.g., biology, chemistry, biochemistry, physical sciences, economics, sociology, etc.). Environmental health professionals educated through university environmental health departments or programs typically have this preparation. Education in other science curricula usually provides a background suitable to gain necessary expertise through supplemental training. Local and state agencies and associations regularly provide appropriate training programs. In addition, there are various certification programs that can be used to assure that necessary expertise has been attained. In some states, on-site wastewater treatment system designers, contractors, installers, and regulators receive similar training and become certified through the same training process. This creates consistency among regulators and contractors, and increases regulators' credibility among the community that they are regulating.

The local health department is often charged with residential and commercial on-site wastewater treatment system design evaluation, issuing permits, and ensuring proper installation, maintenance, and monitoring of on-site wastewater treatment systems. Local health departments are also often responsible for addressing citizen nuisance complaints associated with problems with on-site wastewater treatment systems, such as bad odors or system failure. Local health department officials should be guided by state and local codes and ordinances. State and federal environmental protection agencies may provide guidance, such as NPDES standards, concerning issues for which they serve as the primary regulatory agency.

The primary responsibility for municipal wastewater collection and treatment generally lies with the local public works and wastewater treatment facilities. These public services are regulated by state and federal environmental protection agencies, which are guided by state and federal legislation. However, local public health authorities should be involved in related issues that may impact negatively on public or environmental health. These include issues that may result in human health concerns, such as pathogenic bacteria or hazardous chemicals in wastewater, environmental damage such as fish kills or algae blooms, and aesthetic concerns such as bad odors or appearance. Local public health agencies have a responsibility to both identify and respond to problems that may result in adverse public or environmental health effects resulting from improper wastewater generation, collection, storage, treatment, and/or disposal. Local public health agencies should work with other public agencies involved in wastewater collection and treatment to limit adverse public or environmental health effects resulting from improper wastewater management. These agencies may include local public works departments, water reclamation districts, or state and federal environmental protection agencies.

Local health departments may play a particularly important role in evaluating the cumulative impacts that wastewater management may have on a region or a community. Multiple on-site wastewater treatment system failures in the same geographic area may have a substantial impact on water quality. Regional planning issues, such as the need to provide central treatment plants as opposed to relying on individual wastewater treatment systems, should include substantial input from the local health department. This input is not usually a regulated responsibility, but it is necessary for the local health department to best fulfill its overall objective of protecting public health.

Current Issues and Opportunities

The public is better educated and informed concerning issues associated with water pollution than ever before. Stories associated with water pollution are found daily in newspapers and television news broadcasts. It is an important responsibility of local public health officials to provide a balanced view and to further educate the public concerning these issues.

Cumulative impacts resulting from wastewater management practices can extend far beyond local jurisdictions. For example, the formation of a dead zone in the Gulf of Mexico has been linked with upstream practices in the Mississippi River watershed. These practices have resulted in thousands of square miles of ocean with reduced dissolved oxygen, supporting little or no aquatic life, and may be a result of human contamination of the Mississippi and other rivers with oxygen-depleting components from point and nonpoint source wastewater pollution. Similar pollution occurs in the Chesapeake Bay and San Francisco Bay, as well as the Great Lakes.

A total maximum daily load (TMDL) of NPDES-permitted, point-source wastewater effluent has been proposed to limit cumulative discharge of wastes to a receiving watercourse. Agricultural nonpoint sources, such as large animal containment facilities for intensive poultry, swine, and cattle production, contribute to water pollution, as well as local and regional nonpoint wastewater pollution. On-site wastewater treatment systems also may fail, leading to contamination of surface waters or soil-groundwater systems. Efforts are being made at the federal, state, and local level to address problems associated with centralized and decentralized wastewater treatment systems to limit water contamination.

These and other human practices have led to imbalances in natural aquatic systems, resulting in the emergence (or re-emergence) of waterborne pathogens, concerns about chemical contaminants, and physical disruption of natural aquatic processes.

In most cases, human illness or environmental degradation resulting from improper wastewater management may be prevented or limited through the application of proper environmental controls. A proactive role by public health agencies and boards of health is crucial to identify potential problems before they occur and to implement proper measures to prevent or limit exposures to wastewater contaminants. It is essential to remain current in knowledge of issues related to public health and environmental concerns, including wastewater management.

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