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Wastewater Treatment and the Role of Laboratory Professionals

ABSTRACT *Wastewater treatment combines biological, chemical, and physical unit processes to purify large volumes of sewage. Each unit process—often based on a naturally occurring process—targets specific contaminants in a unique way. By analyzing wastewater constituents at various stages of treatment, laboratory professionals play a vital role in the efficient operation of wastewater treatment plants and, thus, help to protect the environment and public health.*

This is the second article in a 3-part continuing education series on waste. Upon completion of this article the reader will be able to describe the basic processes used at wastewater treatment facilities prior to discharge of treated wastewater into a stream or river.

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Few of us realize what happens to wastewater after we flush it down the drain. We know that a network of pipes under our streets eventually leads to a wastewater treatment facility; but how does a wastewater treatment facility work, and what happens to the water?

When wastewater is introduced into streams, naturally occurring microorganisms consume the organic waste material. The result is a decrease in the dissolved oxygen concentration caused by microbial respiration in the stream. Re-aeration, the natural transfer of oxygen between the air and liquid, replaces the oxygen. But depending on the difference between the volumes of wastewater and stream, oxygen may not be replaced quickly enough to overcome the depletion. If it is not, the stream may become deoxygenated, suffocating the aquatic organisms.

Wastewater Treatment

The first underground drains, or sewers, were constructed by the Romans to provide a means to remove rainwater. Human waste, however, was excluded from sewers until the late 19th century, when scientists discovered that contaminated water was related to the rapid spread of disease during the great epidemics. Even then, human waste transported in sewers was still not treated before it was discharged into streams. This resulted in aesthetic, health, and environmental problems because the uncontrolled discharge of wastewater surpassed the natural ability of waterways to maintain their purity. It was not until Koch and Pasteur announced their germ theory that wastewater treatment facilities came into being.[1]

With the goal to improve water quality, modern wastewater treatment facilities take advantage of biological, chemical, and physical principles to accelerate natural processes under controlled conditions. Such treatment methods are known as unit processes. A typical plant uses many unit processes to remove specific contaminants before it discharges the treated water into waterways. A diagram of a typical treatment facility is presented in Figure 1.

Biological Processes

The most important biological method is the activated sludge process. This unit process introduces naturally occurring microorganisms to consume sludge contaminants, resulting in conversion of the remaining nonsettleable and soluble organic material into settleable organic material (Fig 2 and Fig 3).

The activated sludge process works like the natural processes in a stream, although the former requires a smaller area. The process takes place in a basin where controlled conditions encourage the proliferation of microorganisms that consume

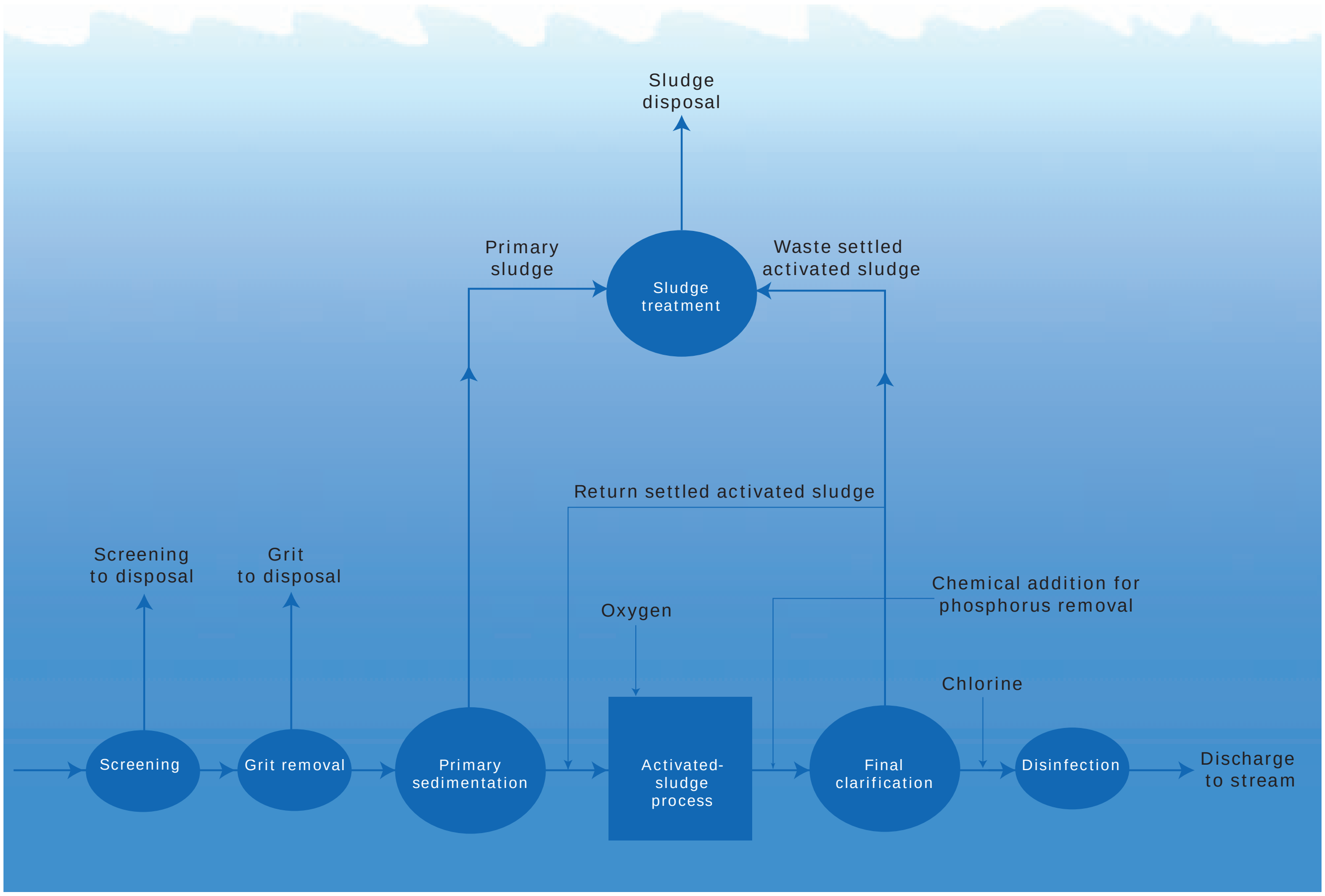


Fig 1. Schematic of a typical wastewater treatment facility.

organic contaminants. Oxygen is supplied for respiration, the pH is kept between 6.5 and 8.5, and nutrients are provided to maximize the microbial reproduction rate.

Activated sludge generally consists of bacteria, protozoa, rotifers, and sometimes nematodes. Bacteria—the predominant microorganism—stabilize the organic matter and form settleable aggregations of cells in suspension. Although all types of bacteria can be found in activated sludge, the nature of the organic material determines which genera will predominate.[2]

As for the free-swimming ciliated protozoa and rotifers, they improve the settleability of the activated sludge. Protozoa do not help to stabilize the organic material, but they feed on the bacteria that consume it. Rotifers devour larger fragments of the activated sludge, and their presence signifies a stable biological system.

Controlling population dynamics also contributes to the biological removal of ammonia. For example, aerobic nitrifying bacteria (*Nitrosomonas* species and *Nitrobacter* species) convert ammonia to nitrate. Other microbial groups are used in treating toxic organic materials as well.

The increased microbial population consumes the organic material more rapidly, producing activated sludge that can be settled by gravity in the final clarifier (Fig 4). To maintain the optimal microbial population, part of the settled activated sludge (in the clarifier) is returned to the basin, and another portion is wasted to prevent overpopulation.

Chemical Processes

Chemical unit processes include adsorption, disinfection, gas transfer, and precipitation. Treated wastewater must be disinfected before it is released into waterways. The traditional disinfectant is chlorine because it is toxic to

Fig 2. An activated sludge basin provides biological treatment of wastewater by providing conditions that encourage the proliferation of microorganisms that consume organic contaminants.

Fig 3. A floating mixer within the activated sludge basin keeps the biomass suspended.

microorganisms, soluble in water, and relatively inexpensive. But chlorine also has negative effects on aquatic organisms. In fact, its potential to form undesirable by-products has resulted in legislation to limit the amount of chlorine that can be discharged into waterways. Other ways to disinfect treated wastewater include ozonization, adding sulfur dioxide, and exposure to UV radiation.

Precipitation removes inorganic contaminants such as phosphorus, which treatment facilities are required to remove because it supports the growth of undesirable algae in waterways. One way to eliminate phosphorus is to add lime, aluminum sulfate, ferric sulfate, or ferric chloride to wastewater. These compounds react to form phosphorus-containing precipitants that settle in the primary sedimentation basin or final clarifier. Precipitation can also be used to remove heavy metals.[3]

Physical Processes

Physical unit processes rely on gravity or mechanical devices to remove contaminants. Typically, the first unit process is a screen that removes large objects that could damage or interfere with the operation of pumps or subsequent unit processes. Next comes a grit-removal system to handle settleable inorganic substances such as sand and soil particles. If not removed, grit will cause premature wear on pumps and other mechanical devices throughout the plant. Grit removal systems harness the force of gravity to remove particles according to their weight.

At the primary sedimentation stage, the remaining settleable materials collect at the bottom of the basin as nonstabilized organic material, or primary sludge, which is transferred to another unit process for stabilization. The partially purified liquid supernatant now consists mostly of nonsettleable and soluble organic and inorganic materials in water. Primary sedimentation removes approximately 60% of the suspended matter and 30% of the total organic waste loading material.

Wastewater Analysis

An important part of wastewater processing is the accurate quantitative measurement of wastewater constituents during various stages of treatment. This is where laboratory professionals play a vital role. Wastewater flow rates and characteristics constantly fluctuate, and accurate analyses make it possible to track the effectiveness of the purification process.

An important quantity in wastewater treatment is the organic content. The most frequently used marker for this is the biochemical oxygen demand, which is determined by measuring the amount of oxygen taken up by microorganisms as they consume the organic waste. The level of another parameter, total suspended solids, determines how much solid material will be collected during sedimentation and measures the amount of solid expected to settle in the waterway after

Internet Resources

Here are some Internet sites that offer more information on topics discussed in this issue of Laboratory Medicine.

BioServe Space Technologies

BioServe Home page, University of Colorado in Boulder Web site
http://www.colorado.edu/engineering/BioServe/

BioServe Space Technologies Home page, Kansas State University (Manhattan, KS) Web site
http://www.ksu.edu/bioserve/

The Space Product Development Web site, National Aeronautics and Space Administration (NASA, Washington, DC), provides a list of Commercial Space Centers with descriptions and links for each.
http://spd.nasa.gov/csc.html

Coagulation

A list of coagulation tests with reference values, uses, and interpretations, from the Coagulation Laboratories, Department of Pathology, are available on the Stanford University School of Medicine (Stanford, CA) Web site.
http://www-med.stanford.edu/school/clin.labs/coag.html

Hematology—Peripheral Blood Smears

An image of a Wright-stained peripheral blood smear from a patient with alpha thalassemia major, is available on WebPath: The Internet Pathology Laboratory (Edward C. Klatt, MD, University of Utah, Salt Lake City) Web site.
http://www-medlib.med.utah.edu/WebPath/COW/COW011.html

The "Hematology Image Atlas" is available on the Harvard Medical School (Boston, MA) Web site.
http://hms.medweb.harvard.edu/HS_Heme/AtlasTOC.htm

Wastewater

The latest National Water Quality Inventory Report to Congress, "The Quality of Our Nation's Water: 1996," US Environmental Protection Agency (EPA, Washington, DC), Office of Water, is available on the EPA Web site.
http://www.epa.gov/305b/execsum.html

The Office of Wastewater Management, Office of Water, EPA, Home page includes information about municipal technologies, industrial pretreatment, biosolids, and water efficiency.
http://www.epa.gov/owm/

These sites were accessed February 29, 2000, and are offered for reader information only. A site's presence on this list does not constitute an endorsement by the ASCP.

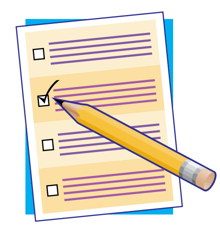
Fig 4. The activated sludge biomass begins to settle in the final clarifier. To maintain an optimal microbial population, part of the settled activated sludge from the clarifier is returned to the activated sludge basin, while another portion is wasted to prevent overpopulation.

treatment of released water. The procedure determines the weight of solids removed (from a given sample volume) by a filter of a specific mesh size.

Laboratory professionals also measure levels of ammonia, phosphorus, and fecal coliform to evaluate the efficiency of the treatment process. Other tests, which assist in process control, include microscopic examinations of biomass to determine population dynamics and measurements of dissolved oxygen, pH, and temperature in the activated sludge basins.

Conclusion

Wastewater treatment facilities apply biological, chemical, and physical principles under controlled conditions to remove contaminants from large volumes of water. With the aid of laboratory professionals, such treatment plants accomplish this task in an area much smaller than that required by a naturally occurring process. Water released from these plants has minimal negative effects on the environment and public health, thus permitting the use of waterways for recreation. l



Test Your Knowledge!
Look for the CE Update exam on Waste (003) in the May issue of *Laboratory Medicine.* Participants will earn 3 CMLE credit hours.

References

1. Metcalf and Eddy, Inc. *Wastewater Engineering, Treatment, Disposal, Reuse*. 2nd ed. New York: McGraw-Hill; 1979.
2. McKinney R. *Microbiology for Sanitary Engineers*. New York: McGraw-Hill; 1962.
3. Sawyer C, McCarty P. *Chemistry for Sanitary Engineers*. 2nd ed. New York: McGraw-Hill; 1967.