



Microorganisms in Wastewater Treatment

Samuel Brooks*

Department of Microbiology, Riverstone University, Manchester, United Kingdom

DESCRIPTION

Wastewater contains organic matter, nutrients, suspended particles, microorganisms, and chemical substances that must be treated before water is released into the environment or reused. Biological treatment relies heavily on microorganisms to convert organic and inorganic compounds into forms that can be separated or removed. Bacteria are particularly important in activated sludge systems, biofilters, anaerobic digesters, and other treatment technologies.

In aerobic wastewater treatment, microorganisms use oxygen while consuming biodegradable organic compounds. The organic material serves as a source of carbon and energy. As bacteria grow, they form biomass that can aggregate into flocs. These flocs can subsequently be separated from treated water through sedimentation or other processes.

Activated sludge is one of the most widely used biological treatment systems. Wastewater is mixed with microbial biomass in an aeration tank. Oxygen is supplied through mechanical or diffused aeration. Microorganisms consume biodegradable substances, and the resulting biomass is separated from the treated water. A portion of the biomass can be returned to the treatment tank to maintain an appropriate microbial population.

Nitrogen removal involves several microbial processes. Nitrifying bacteria convert ammonia into nitrite and then nitrate under aerobic conditions. Denitrifying bacteria can subsequently convert nitrate into gaseous nitrogen compounds under conditions with limited oxygen and suitable carbon availability. The combination of these processes can reduce nitrogen concentrations in treated wastewater.

Phosphorus removal can also involve microorganisms. Certain bacteria accumulate phosphorus within their cells under specific operating conditions. Biological phosphorus removal systems alternate between environments with different oxygen and chemical characteristics. This selective pressure encourages the

development of microbial communities capable of storing phosphorus.

Anaerobic treatment uses microorganisms in the absence of oxygen. Organic matter is converted through several stages involving different microbial groups. Complex compounds are first broken into smaller molecules. Fermentative microorganisms produce organic acids and other compounds, which are then converted into substrates used by methane-producing archaea. The final stage produces methane and carbon dioxide.

Anaerobic digestion has two major benefits. It reduces organic waste while producing biogas that can be collected and used as an energy source. The remaining digested material may contain nutrients that can sometimes be recovered or reused under appropriate conditions.

Microbial communities in wastewater treatment are sensitive to operating conditions. Temperature, pH, oxygen concentration, nutrient availability, hydraulic retention time, and toxic substances can influence microbial growth. Sudden changes in wastewater composition may disturb treatment performance by affecting sensitive microbial populations.

Molecular methods provide additional information. DNA sequencing can characterize microbial communities without requiring all organisms to be cultivated. Researchers can examine changes in bacterial and archaeal populations under different treatment conditions. Functional gene analysis can also provide information about biological pathways associated with nitrogen or phosphorus transformation.

Wastewater treatment is increasingly connected with resource recovery. Nitrogen and phosphorus can sometimes be recovered from wastewater and reused as fertilizers. Biogas can be used for energy production. Treated water may be suitable for selected forms of reuse after meeting applicable safety requirements. Microbiology is important in each of these processes because microorganisms influence the conversion and removal of many wastewater components.

Correspondence to: Samuel Brooks, Department of Microbiology, Riverstone University, Manchester, United Kingdom, E-mail: samuel.brooks@riverstone.edu

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CONCLUSION

Microorganisms are essential to many wastewater treatment processes. Aerobic bacteria degrade organic matter, nitrifying communities transform ammonia, denitrifying organisms remove nitrate, and anaerobic microbial communities contribute to biogas production. Understanding microbial population dynamics allows treatment facilities to maintain suitable operating conditions. Advances in molecular analysis

and resource recovery research are expanding the applications of microbial biotechnology in water management. Emerging contaminants such as pharmaceutical residues, personal care chemicals, and industrial compounds are receiving increasing attention. Some microorganisms can transform these substances, although removal efficiency varies widely. Research is examining microbial degradation pathways and treatment conditions that may improve removal.