



Microbially Enhanced Phosphorus and Nitrogen Removal

Introduction

Nutrient pollution, particularly phosphorus (P) and nitrogen (N), is a major cause of eutrophication in aquatic environments.

Microbial processes play a crucial role in removing these nutrients from wastewater, surface water, and sediments.

Enhanced biological nutrient removal (BNR) uses microorganisms to uptake, store, and transform phosphorus and nitrogen efficiently.

Importance of Nitrogen and Phosphorus Removal

Excess nitrogen leads to:

- 1- Ammonia toxicity
- 2- Nitrate contamination of groundwater
- 3- Algal blooms

Excess phosphorus leads to:

- 1- Eutrophication
- 2- Oxygen depletion
- 3- Loss of biodiversity
- 4- Regulatory limits require advanced treatment before discharging water.

Microbial Processes in Nitrogen Removal

Nitrogen exists in several forms: ammonia ($\text{NH}_3/\text{NH}_4^+$), nitrite (NO_2^-), nitrate (NO_3^-), and organic nitrogen.

First \\\ Nitrification (Aerobic)

Conversion of ammonia → nitrite → nitrate

Key microorganisms:

- Ammonia-oxidizing bacteria (AOB) – Nitrosomonas
- Nitrite-oxidizing bacteria (NOB) – Nitrobacter

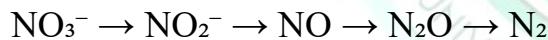
Reaction steps:



Second \\ Denitrification (Anaerobic)

- Conversion of nitrate → nitrogen gas (N_2), which is released into the atmosphere
- Performed by heterotrophic bacteria such as Pseudomonas, Paracoccus
- Requires organic carbon as electron donor

Reaction example:



Third \\ Anammox (Anaerobic Ammonium Oxidation)

- $\text{NH}_4^+ + \text{NO}_2^- \rightarrow \text{N}_2 + 2 \text{H}_2\text{O}$
- Performed by Planctomycetes
- Reduces aeration and carbon requirements compared to traditional nitrification/denitrification

Microbial Processes in Phosphorus Removal

Microbial phosphorus removal relies on Polyphosphate Accumulating Organisms (PAOs)

Enhanced Biological Phosphorus Removal (EBPR)

A- Anaerobic-Aerobic cycling promotes phosphorus uptake:

- 1- Anaerobic phase: PAOs take up volatile fatty acids (VFAs) and release phosphate
- 2- Aerobic phase: PAOs take up phosphate beyond growth requirements and store as polyphosphate

B- Common PAOs: *Candidatus Accumulibacter phosphatis*, *Tetrasphaera*

Integration of Nitrogen and Phosphorus Removal

Systems often combine nitrification-denitrification and EBPR for simultaneous N and P removal.

Typical setups:

- 1- Sequencing batch reactors (SBR)
- 2- Membrane bioreactors (MBR)
- 3- Anaerobic/anoxic/aerobic zones

Factors Affecting Microbial Nutrient Removal

- 1- Temperature: Optimal microbial activity occurs around 20–30°C
- 2- pH: Neutral to slightly alkaline conditions favor nitrifiers and PAOs
- 3- Dissolved Oxygen (DO): Required for nitrification and aerobic phosphorus uptake
- 4- Carbon Source: Essential for denitrification and anaerobic phosphorus release
- 5- Hydraulic Retention Time (HRT): Sufficient time needed for microbial transformations

Emerging Techniques and Applications

A- Simultaneous N and P removal using shortcut nitrogen processes (e.g., partial nitritation-anammox)

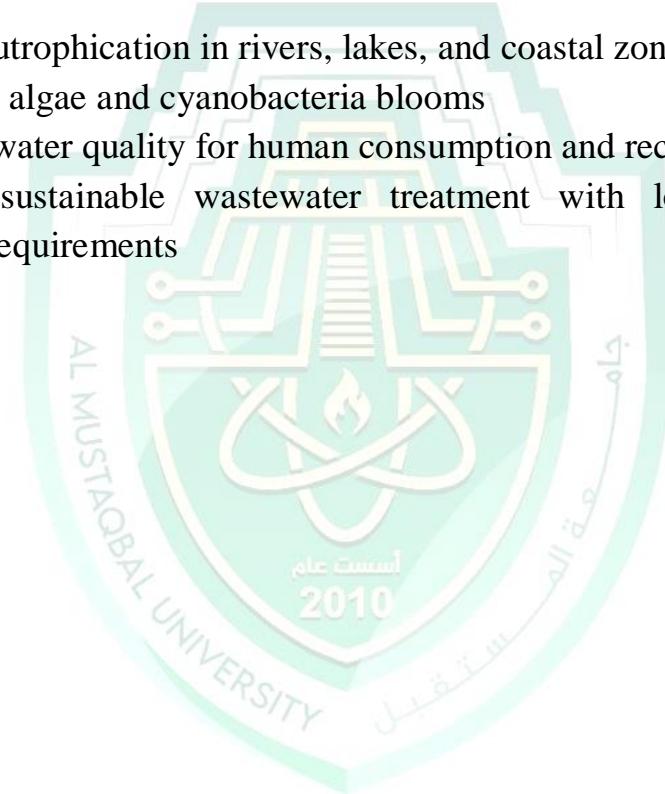
B- Use of microbial consortia and bioaugmentation to enhance nutrient removal

C- Integration with constructed wetlands and biofilms for decentralized treatment

D- Real-time monitoring using microbial sensors and molecular biology tools

Environmental and Health Benefits

- 1- Reduces eutrophication in rivers, lakes, and coastal zones
- 2- Minimizes algae and cyanobacteria blooms
- 3- Improves water quality for human consumption and recreation
- 4- Supports sustainable wastewater treatment with lower energy and chemical requirements



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