# 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 ($NH_3/NH_4^+$), 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:

$NH_4^+ + O_2 \rightarrow NO_2^- + H_2O + H^+$

$NO_2^- + O_2 \rightarrow NO_3^-$

**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:

$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$

**Third \\ Anammox (Anaerobic Ammonium Oxidation)**

- $NH_4^+ + NO_2^- \rightarrow N_2 + 2\ H_2O$
- 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