Nutrient Removal from Wastewater by Wetland System

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Introduction

- USEPA defines wetlands as “those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions”

- Wetlands can be naturally occurring or constructed
Introduction

- Natural wetlands include marshes, swamps, bogs and fens.
- Constructed wetlands are designed for a particular need
- Functions of wetlands include: habitat for aquatic and terrestrial plants, nesting sites for migrating birds, recreational value and treatment of wastewater
- Constructed wetlands are more efficient than natural wetlands
Constructed Treatment Wetlands

- Two types: surface flow constructed wetlands and subsurface flow constructed wetlands
- Subsurface wetlands are more efficient than surface wetlands
- Constructed wetlands are designed for a specific inflow and outflow rate, HRT and hydraulic loading rate
- Inputs – wastewater inflow and precipitation
- Outputs – effluent, ET and transpiration
- Wetlands are lined to prevent groundwater contamination
Constructed wetlands are used to treat wastewater from various sources:

- Sewage
- Municipal wastewater
- Septic tanks
- Storm water
- Agricultural wastewater
- Landfill leachate
- Partially Industrial wastewater
- Runoff from highways
Components

- **Vegetation**: commonly used hydrophytes are: reed canary grass, softstem bulrush, sedges, etc. Functions include photosynthesis, reduce inflowing velocities, uptake of nutrients, etc.

- **Substrate**: Includes soil, sand, gravel, rocks, etc. Functions include provide surface area for biological and chemical processes, site for suspended solids, etc.

- **Water column**: Acts as medium of transport for organics solids, nutrients, etc.

- **Living organisms**: Bacteria, fungi, protozoa, etc help in biochemical reactions
Wastewater Treatment

- Wastewater treatment includes removal of organic material, suspended solids, toxic waste, pathogens and nutrients like nitrogen and phosphorous.
- Processes involved in the treatment of wastewater in the wetlands are filtration, sedimentation, precipitation of heavy metals, photosynthesis and respiration by plants, fermentation, nitrification, denitrification, etc.
Nitrogen Removal

- Main sources of nitrogen include agricultural wastewater and sewage
- High levels in nitrogen can cause eutrophication in lakes and blue baby syndrome
- Nitrogen is removed by bacterial conversion and plant uptake of nitrogen
- Nitrogen cycle has three main processes – ammonification, nitrification and denitrification
Simplified Nitrogen Cycle

- Organic N
- $N_2$
- $NH_4^+$
- $N_2O$
- $NO_2$
- $NO_3^-$

Mediating Factors:
- Biological
- Physical
- Chemical
Nitrogen Removal

- **Ammonification**: Conversion of organic N to $\text{NH}_4^+$

- **Nitrification**: Two step process: Conversion of $\text{NH}_4^+$ to $\text{NO}_2^-$ and conversion of $\text{NO}_2^-$ to $\text{NO}_3^-$
  
  $\text{NH}_4^+ + \text{O}_2 \rightarrow \text{NO}_2^- + 2\text{H}^+ + \text{H}_2$
  
  $2\text{NO}_2^- + \text{O}_2 \rightarrow 2\text{NO}_3^-$

- **Denitrification**: Two step process: conversion of $\text{NO}_3^-$ to $\text{NO}_2^-$ and conversion of $\text{NO}_2^-$ to N$_2$ gas
  
  $\text{NO}_3^- + \text{C (organic)} \rightarrow \text{N}_2 + \text{CO}_2 + \text{H}_2\text{O}$
Phosphorus Removal

- Main source of phosphorus in wastewater in agricultural
- High levels of phosphorus can cause eutrophication in lakes and ponds
- P is present in water in the form of orthophosphate and organic P
- P is removed by adsorption to iron, calcium, magnesium ions present in the sediments
Phosphorus cycle
Phosphorus Removal

- Adsorption under aerobic conditions forms stronger bonds than under anaerobic conditions
- Adsorption to iron takes place under neutral to acidic pH conditions
- Adsorption to calcium takes place under aerobic conditions from basic to neutral pH conditions
- Adsorption of P from removes it from wastewater
- Adsorption is a reversible process
Phosphorus Removal

- P can also get precipitation with iron or aluminum ions
- P is also removed by decomposition of litter and organic matter
- P can also be fixed in clay minerals
- Plants uptake of P also removes P from wastewater
- Unlike nitrogen, P is not totally removed from the system
Factors Affecting Nutrient Removal

- **Nitrogen**
  - Nitrification is effected by availability of dissolved oxygen, temperature, pH. Denitrification is effected by absence of oxygen, temperature, pH and availability of carbon source.
  - Plant uptake of nitrogen is effected by growth rate of plants, concentration of nitrogen in plant tissues and climatic conditions.

- **Phosphorus**
  - Adsorption is effected by availability of oxygen, pH, presence of sediments, substrate capacity to adsorb phosphorus.
Important Factors Affecting Wetland Performance

- Inflow and outflow rate
- Pollutant loading rate
- Hydraulic retention time
- Hydraulic loading rate
- Temperature and pH
- Oxygen availability
- Wetland design parameters
  - Substrate
  - Vegetation
  - Living organisms
Factors Affecting Wetland Performance

- According to Sakadevan 1999, low hydraulic loading rate and higher HRT increases wetland performance.
- According to Picard et al. 2005, optimum temperature conditions increase the wetland performance. Presence of suitable hydrophytes also increases performance.
- Fisher and Acreman 2004 proved that nutrient removal depended on nutrient loading rate and HRT. The studies showed that P removal is positively related to P loading and N removal is negatively related to loading.
Factors Affecting Wetland Performance

- According to Fink and Mitsch 2004, wetland should be designed according to the type of nutrient to be removed.
- Andersson et al. 2005, found out that high nitrogen loading rate increased denitrification rate, thereby increasing N removal. Nutrient removal is affected by type of pretreatment given to the wastewater.
- According to Maine et al. 2005, higher pH at the outlet of wetland, increased removal of P by adsorption to Ca ions.
Limitations of Wetlands Systems

- Large land area required
- Long time required for growth of vegetation and achieve treatment rates
- Open standing water can be breeding ground for mosquitoes and insects
- Construction of wetlands can be affected by area with high water table, steep topography.
- Wetlands performance will be depend on usage and climatic conditions
- High construction cost
Advantages of Wetlands

- Low energy input – solar energy is required for survival of plants and living organisms
- Low operational maintenance
- No design life as compared to treatment plants
- Wetlands are more tolerant to varying pollutant loads
Questions