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

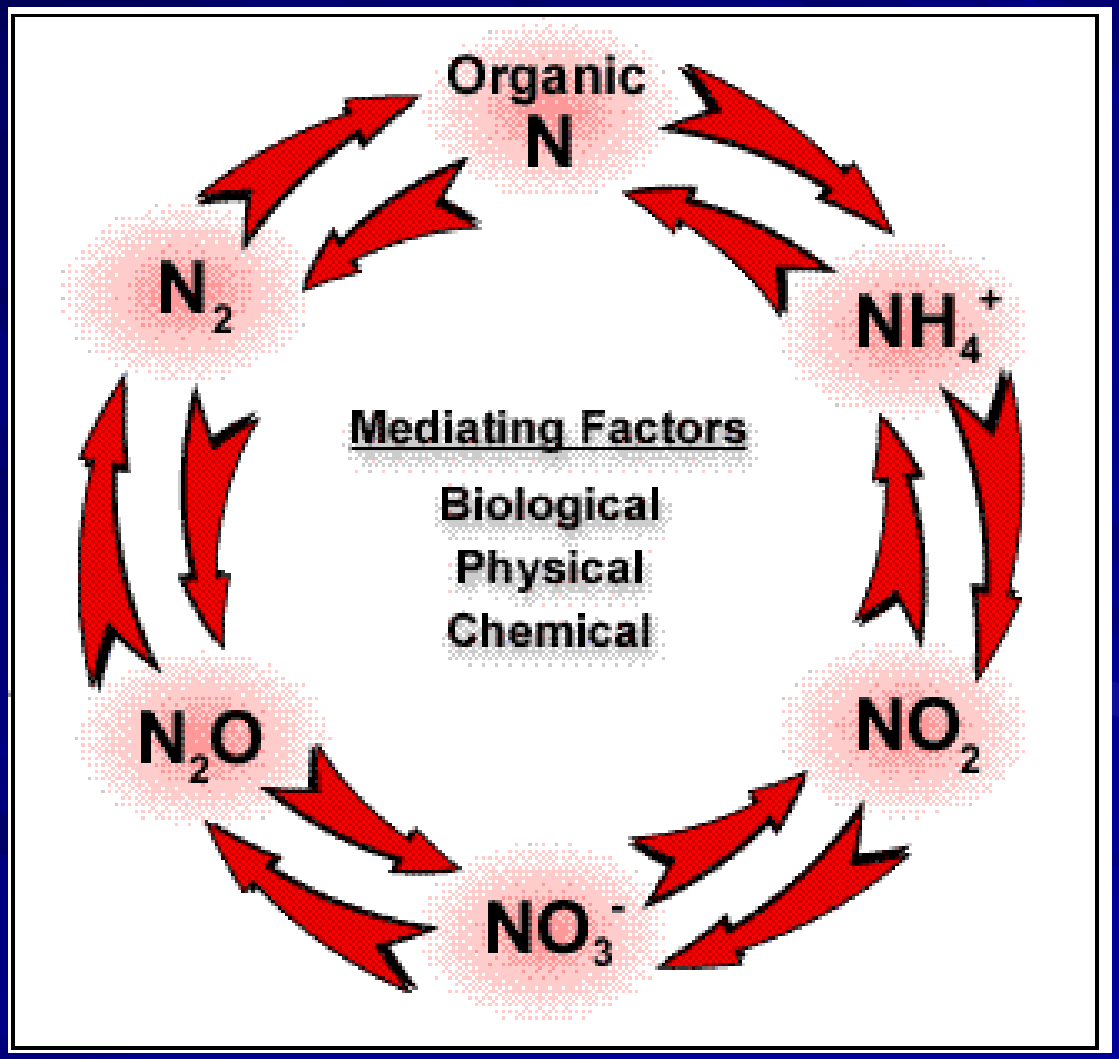
Wastewater Treatment

- 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



Nitrogen Removal

- Ammonification: Conversion of organic N to NH_4^+
- Nitrification: Two step process: Conversion of NH_4^+ to NO_2^- and conversion of NO_2^- to NO_3^-

  $NH_4^+ + O2 \rightarrow NO_2^- + 2H+ + H2$

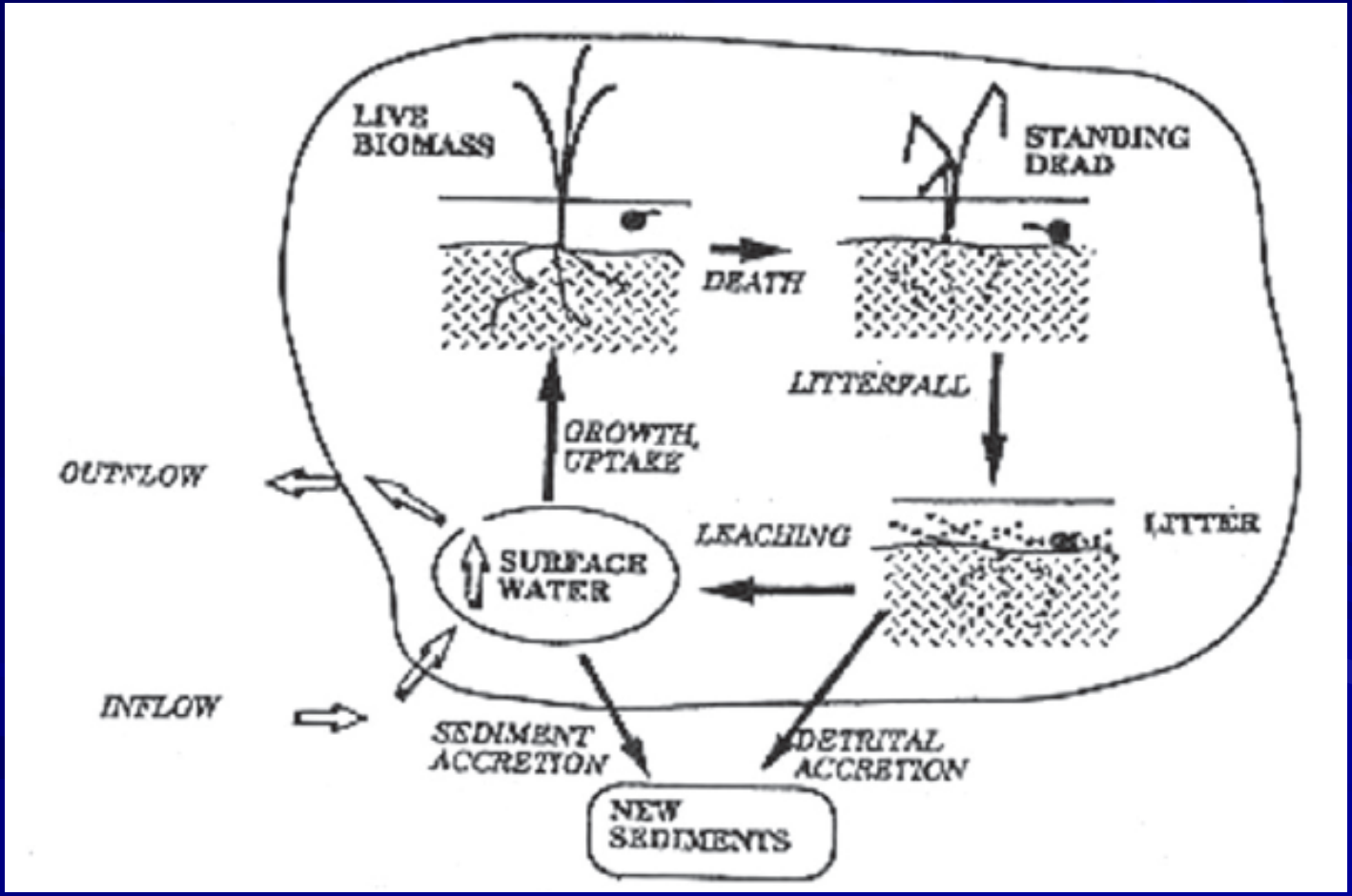
  $2\ NO_2^- + O2 \rightarrow 2\ NO_3^-$
- Denitrification: Two step process: conversion of NO_3^- to NO_2^- and conversion of NO_2^- to N_2 gas

  $NO_3^- + C\ (organic) \rightarrow N2 + CO2 + H2O$

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 liter 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 uasge 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