The EU funded SWIM-SM: developing capacity for Sustainable and Integrated Wastewater Treatment and Reuse

Online Course on Natural Treatment Systems: Basic Principles of Constructed Wetlands

Wetlands for wastewater treatment

Basic principles

by

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Introduction

Why should we purify wastewater?

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etlands for Wastewater Treatment

Introduction

Why should we purify wastewater?

Scale of treatments

Introduction

Why should we purify wastewater?

Scale of treatments

Limitations

Principles of purification

Principles of purification

- Separation and transformation by the following mechanisms:
  - Physical
  - Chemical
  - Biological
- Simultaneously or
- Sequentially

Essential questions

- 1. What is wastewater?
- 2. What do we need to do to purify wastewater?
- 3. What are wetlands?
- 4. How can wetlands purify?
- 5. Natural wetlands or constructed wetlands for wastewater treatment?

1. What is wastewater?

Composition of wastewater

- Organic matter
- Suspended solids
- Nitrogen
- Phosphorous
- Pathogens
- Water
- Toxic compounds
  - metals
  - herbicides etc

Characteristics municipal wastewater (EPA)

Constituent (mg/L)	Septic Tank Effluent[1]	Primary Effluent[2]	Pond Effluent[3]
BOD	129-147	40-200	11-35
Sol. BOD	100-118	35-160	7-17
COD	310-344	90-400	60-100
TSS	44-54	55-230	20-80
VSS	32-39	45-180	25-65
TN	41-49	20-85	8-22
NH_3	28-34	15-40	0.6-16
NO_3	0-0.9	0	0.1-0.8
TP	12-14	4-15	3-4
OrthoP	10-12	3-10	2-3
Fecal coli (log/100ml)	5.4-6.0	5.0-7.0	0.8-5.6

[1]EPA (1978), 95% confidence interval. Prior to major detergent reformulations which reduce P species by ~50%.
[2]Adapted from Metcalf and Eddy, (1991) assuming typical removal by primary sedimentation-soluble BOD = 35 to 45% total.
[3]EPA (1980).

Organic matter

Measured as:

TOC

COD

BOD

Regulators use mainly BOD

Suspended solids

Important component of wastewater

Sedimentation/filtration

Easy to remove

Increasing residence time

Nitrogen

Nitrogen

Nitrogen

- Ammonium
- Organic matter
- Nitrate
- Nitrogen gas
- Dissolved

Phosphorous

Phosphorous

- Food
- Organic matter
- Detergents

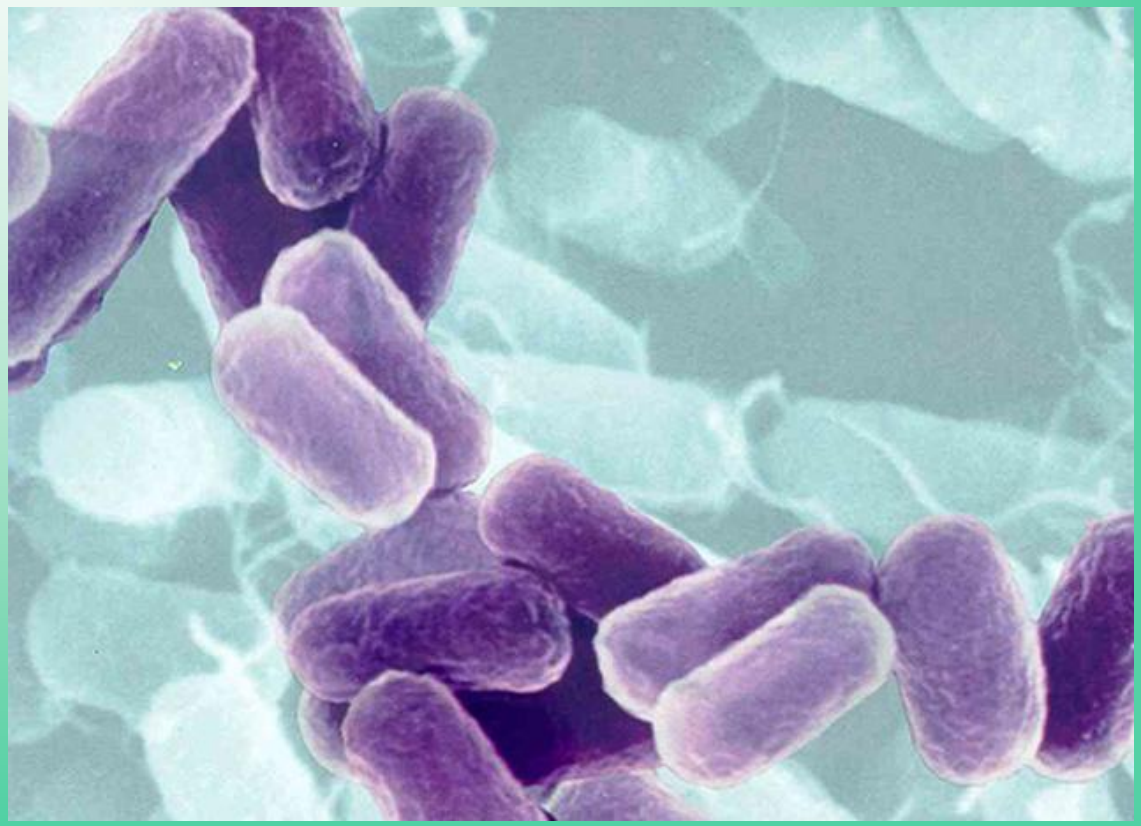
- No gaseous form

Toxic compounds in waste water:

heavy metals
herbicides
pesticides
medicine
endocrine disruptors
pathogens
etc.

Spraying of herbicides

Pathogens



2. What do we need to do to purify wastewater?

- Remove all the components of the wastewater, or
- Convert the components into harmless compounds

Question:

- Why is wastewater not good for the environment?

Answers:

- Wastewater contains nutrients
- This will decrease biodiversity
- Rare species will disappear
- Pathogens
- Etc

Natural wetlands or constructed wetlands?

- Amount of wastewater
- Local conditions
- Available land
- Type of wastewater
- Interest of authorities

And conventional wastewater treatment???

- Cheap
- no prestige
- No skilled manpower needed
- no forex needed for construction
- land has to be available
- etc

3. What are wetlands?

And how are they managed for wastewater treatment?

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A natural wetland???

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Constructed Wetlands for Wastewater Treatment

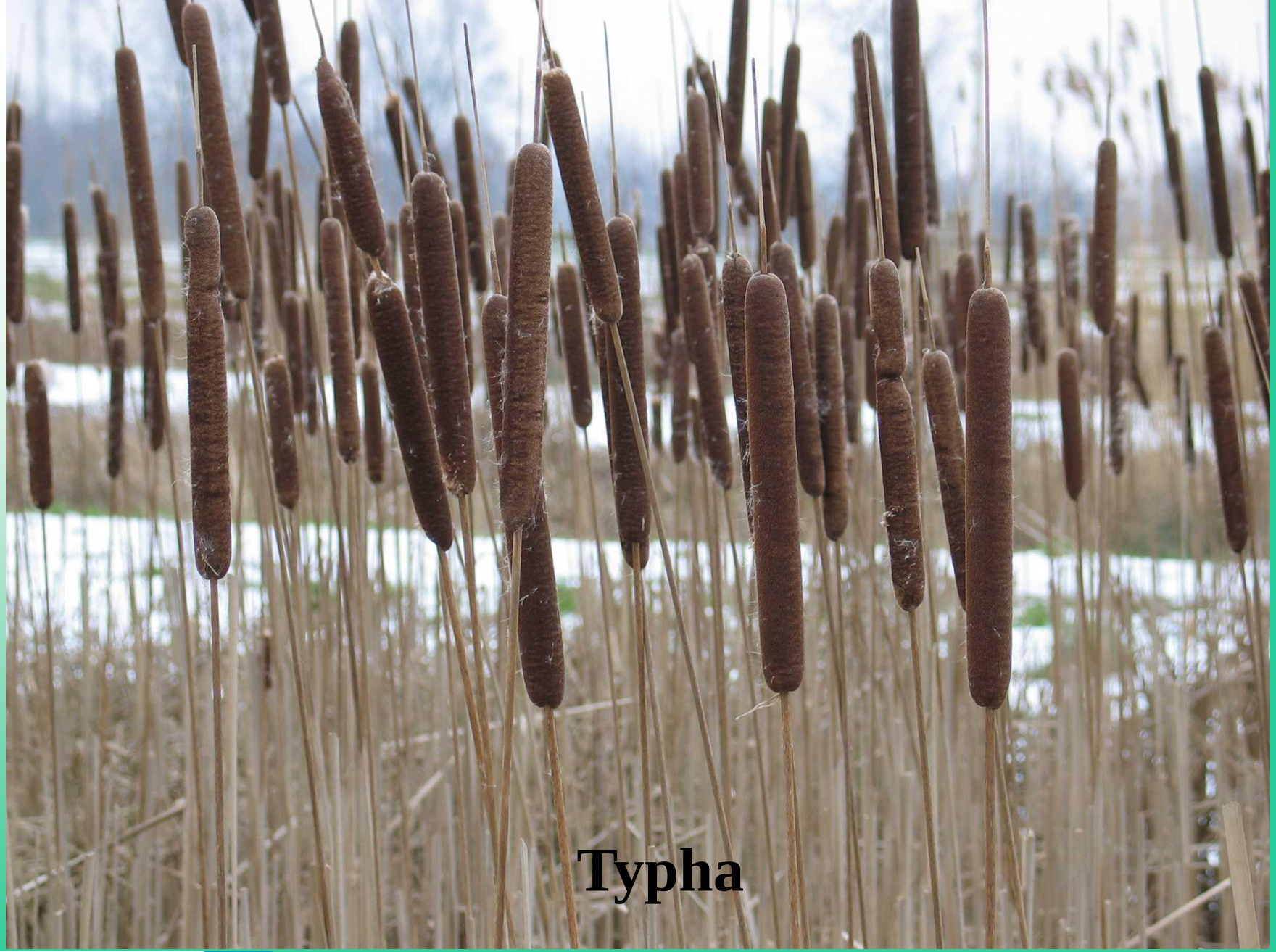
Some wetland plants are important for wastewater purification, like

Typha or cattail

Phragmites or reed

Scirpus or bulrush

***Typha latifolia*, cattail.**
Typhaceae



Typha

CATTAIL DOLLS These dolls are made of all natural Cattail leaves (Typha latifolia). The doll is approximately 12 inches tall. Each dolls comes with a stand and accessories

are made from local birch, willow, black spruce and dried flowers.

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Phragmites

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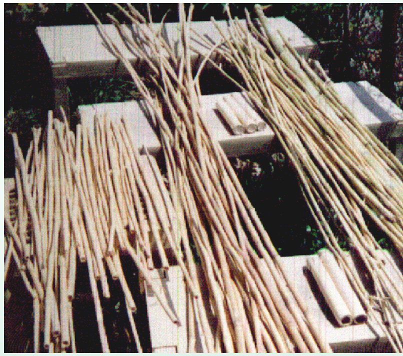
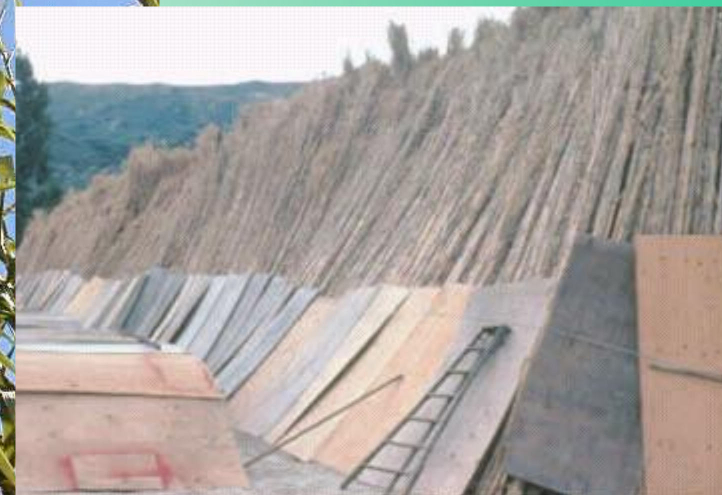
Giant Reed
Arundo donax





4. How can wetlands purify?

Compartments of a wetland

- sediment
- rootzone/pore water
- litter/detritus
- water
- air
- plants
- roots

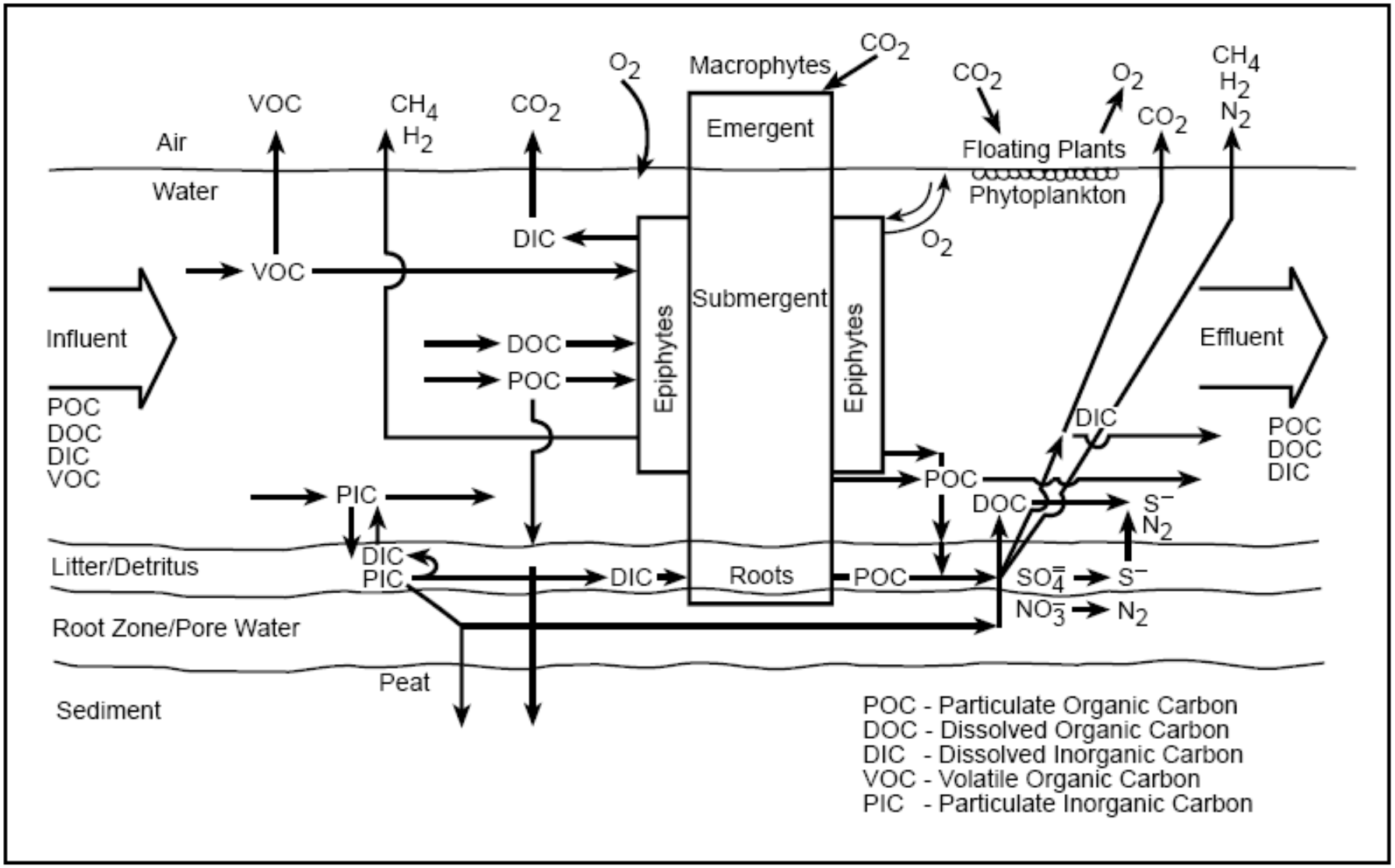


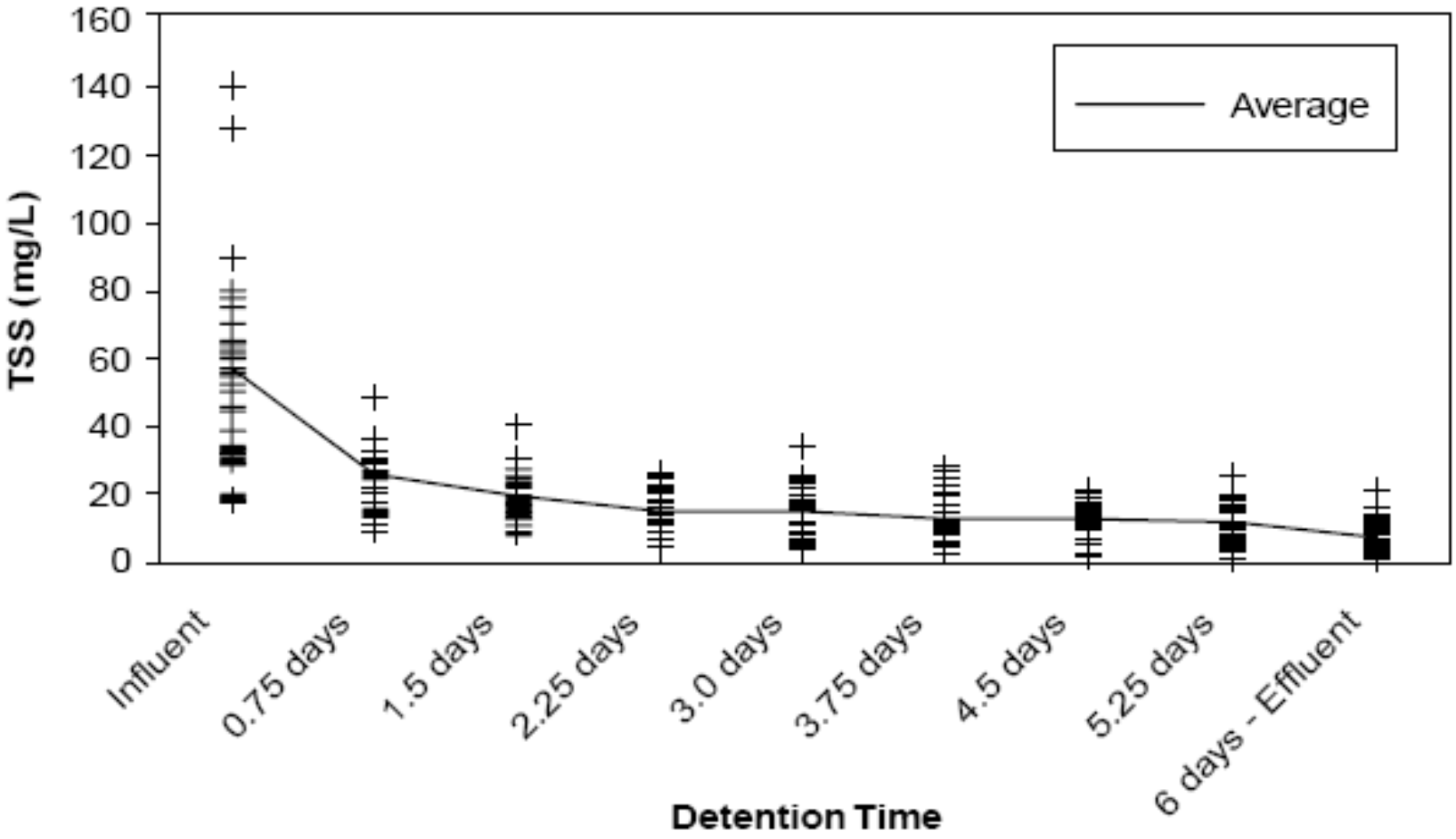
Figure 3-4. Carbon transformations in a FWS wetland

Suspended solids

- Separation by
  - Gravity
  - Filtration
  - Absorption
  - Adsorption
  - Ion exchange

Suspended solids

- **Transformation by**
  - **Chemical reactions**
    - **Oxidation/reduction**
    - **Flocculation**
    - **precipitation**
  - **Biochemical reactions**
    - **Aerobic**
    - **Anoxic**
    - **anaerobic**



Weekly transect TSS concentration for Arcata cell 8 pilot receiving oxidation pond effluent (EPA, 1999)

Biological conversion

Removal by:

- Mineralisation
- Gasification
- Use as building blocks

Nitrogen cycle

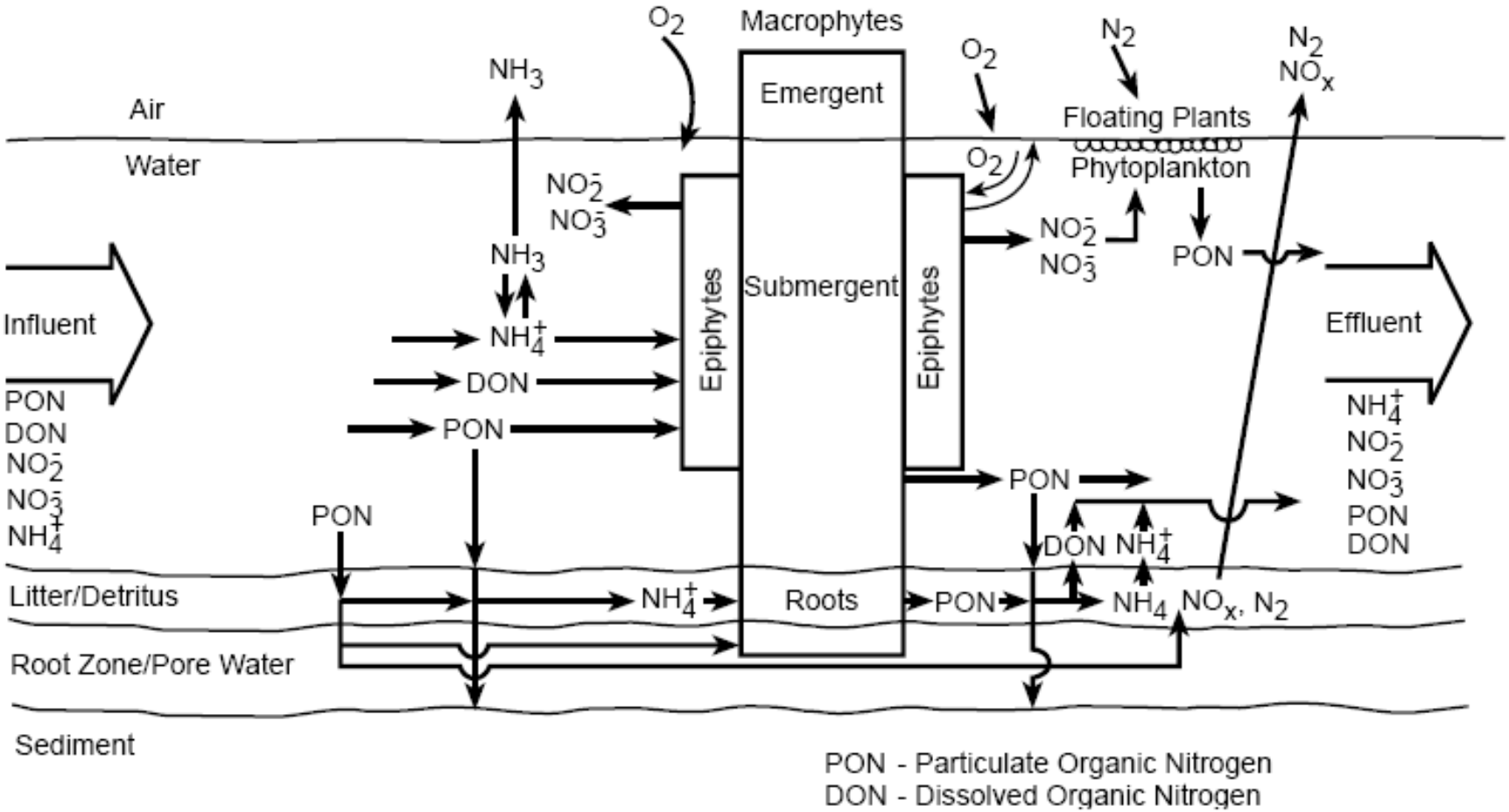


Figure 3-6. Nitrogen transformations in FWS wetlands

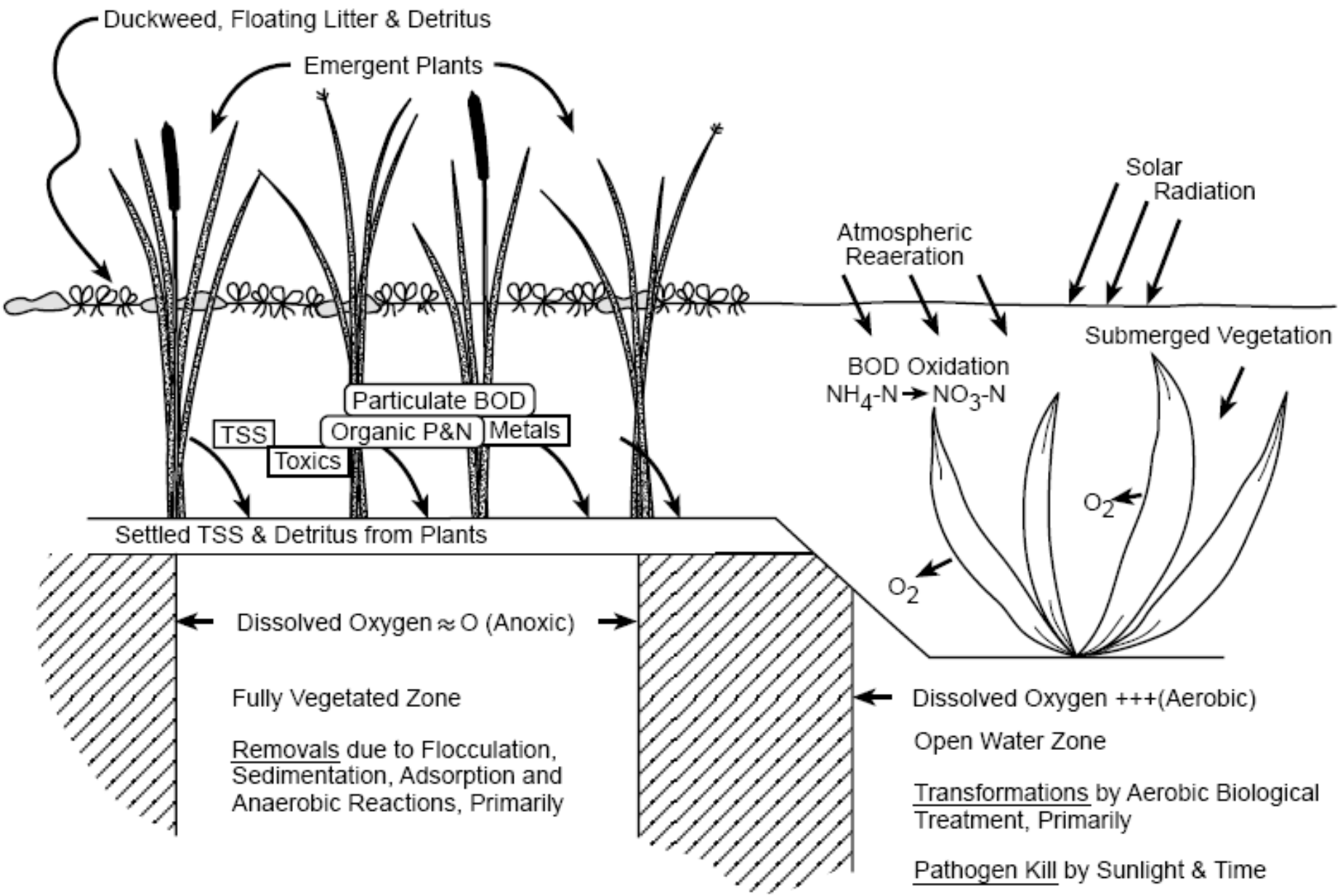
Removal of N
Microbial processes: nitrification and denitrification
nitrification limiting step, intermittent flooding
50-60% of total N-load is denitrified

Oxygen transfer

Biochemical reaction + O2 ---→ mineralisation

Three sources of DO:

- Surface aeration (1 g/m2/d)
- Photosynthesis (2.5 g/m2/d)
- Plant oxygen transfer (0-3 g/m2/d)


Duckweed, Floating Litter & Detritus
Emergent Plants
Solar Radiation
Atmospheric Reaeration
Submerged Vegetation
BOD Oxidation
NH_4-N → NO_3-N
Particulate BOD
TSS
Organic P&N
Metals
Toxics
O_2
O_2
Settled TSS & Detritus from Plants
Dissolved Oxygen ≈ O (Anoxic)
Fully Vegetated Zone
Removals due to Flocculation, Sedimentation, Adsorption and Anaerobic Reactions, Primarily
Dissolved Oxygen +++(Aerobic)
Open Water Zone
Transformations by Aerobic Biological Treatment, Primarily
Pathogen Kill by Sunlight & Time

Phosphorous cycle

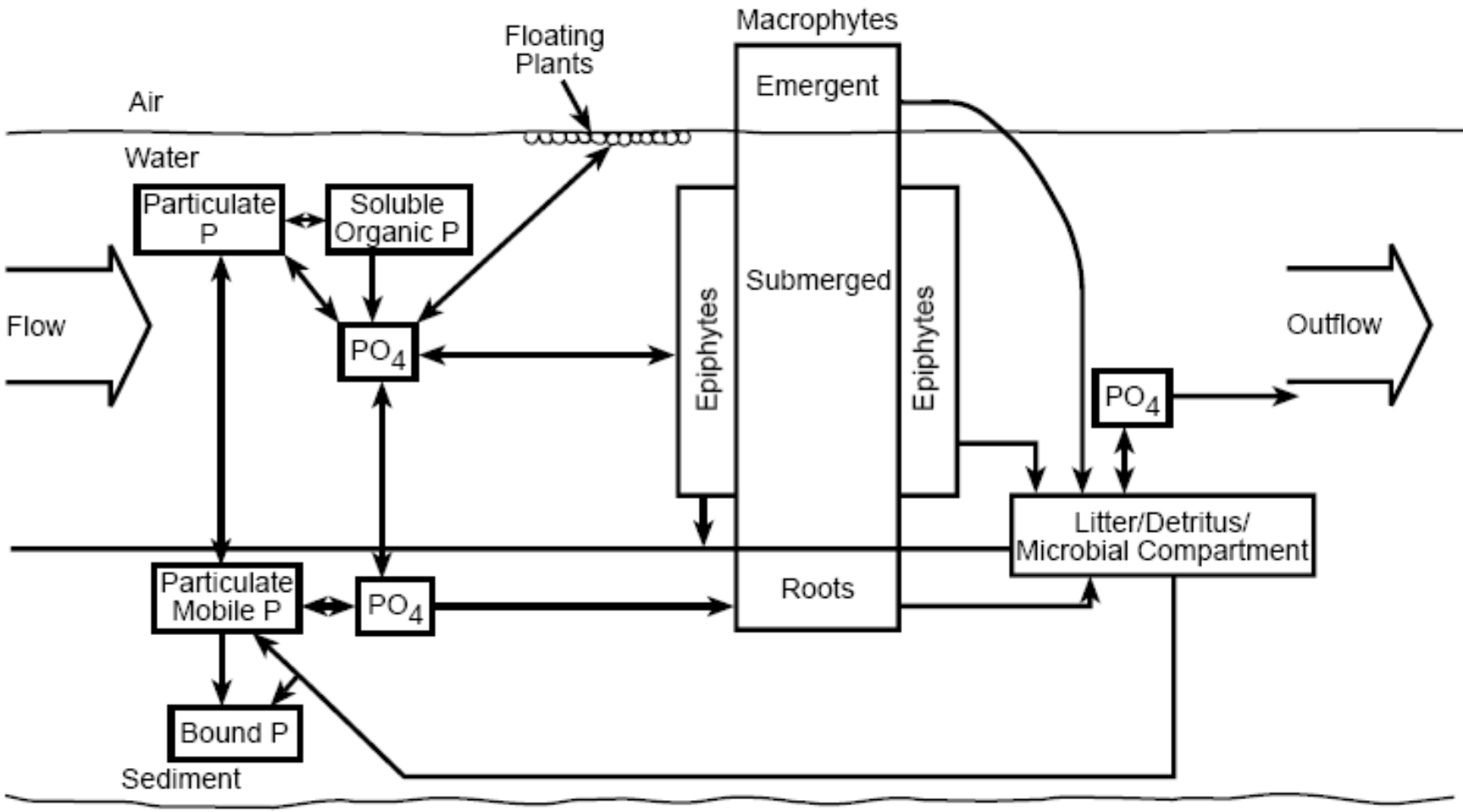


Figure 3-7. Phosphorus cycling in a FWS wetland (adapted from Twinch and Ashton, 1983)

Removal of P

precipitation — **depends on redox condition, soil pH, availibility of Fe, Al and Ca ions.**

Uptake by plants

Absorption:

$PO4^{3-}$ absorbed by peat layers by ion exchange, chemical and physical absorption (influenced by pH, redox potential and Ca, Al and Fe-contents of interstitail water, aerobic, anaerobic, FePO4 prec.)

Role of the water

Role of the microorganisms

Role of the vegetation

Nutrients in plants

nutrient content of plants increases with nutrient availability (fig.)

- -- nutrient uptake by plants only 10-50 % of uptake by other compartments
- -- growth seasonal --> release of nutrients in winter unless incomplete mineralisation
- -- better storage in forested swamps
- -- harvesting (5-25% of annual inflow removal)
- -- no saturation
- -- seasonal storage

Role of the sediment

Role of the manager ?!!

5. Natural wetlands or constructed wetlands for wastewater treatment?

Depends on:

- Quantity of wastewater
- Quality of wastewater
- Availability of land
- Suitable swamp area
- Always needs careful planning