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

Online Course on Natural Treatment Systems: Introduction to Wastewater Treatment

Introduction to Wastewater Treatment

online course

SWIM

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Wastewater: definition

Wastewater is any water that has been adversely affected in quality by anthropogenic influence. It comprises liquid waste discharged by domestic residences, commercial properties, industry, and/or agriculture and can encompass a wide range of potential contaminants and concentrations. In the most common usage, it refers to the municipal wastewater that contains a broad spectrum of contaminants resulting from the mixing of wastewaters from different sources.

Sewage is correctly the subset of wastewater that is contaminated with feces or urine, but is often used to mean any waste water.

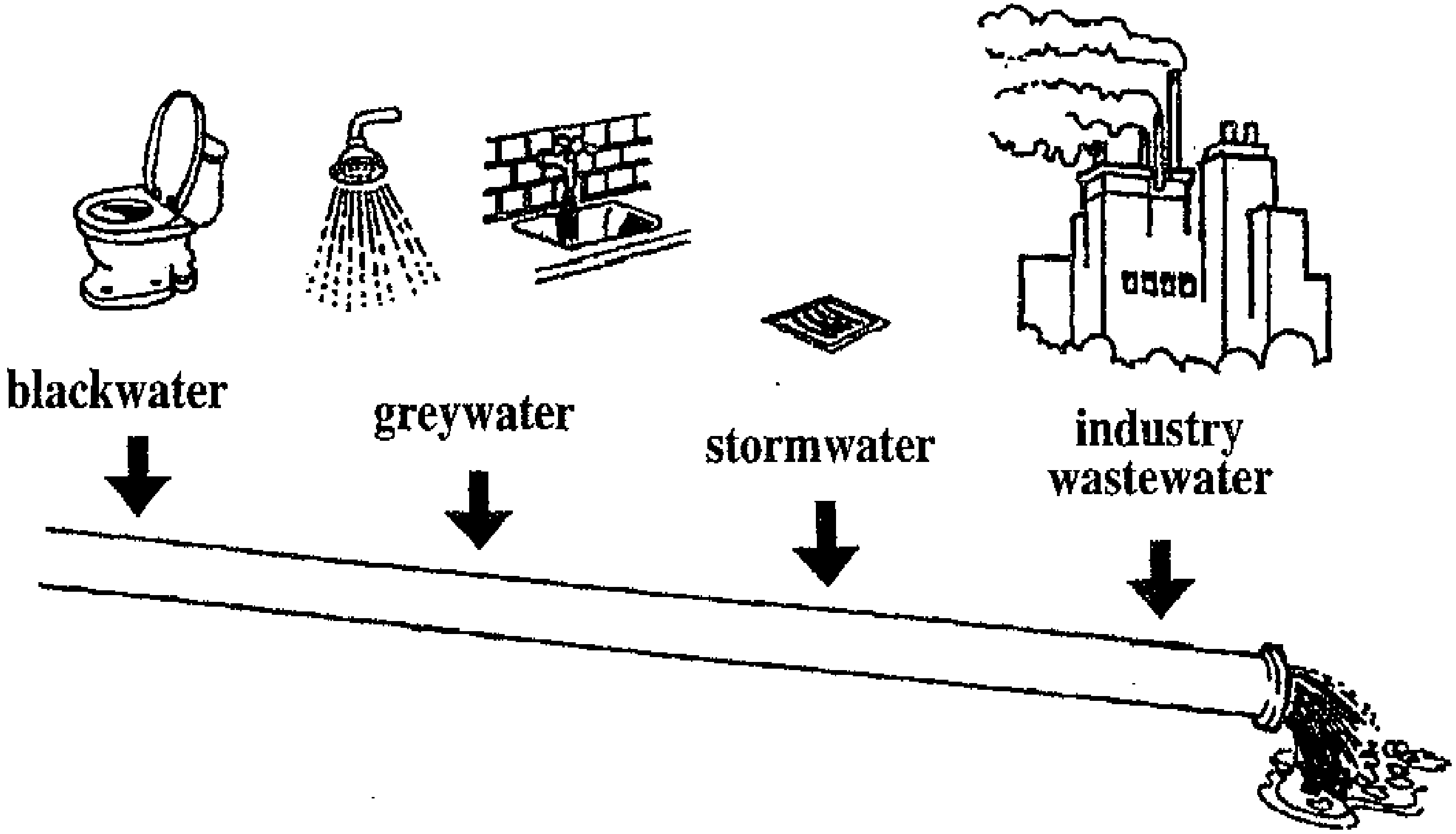
Source: Wikipedia

Wastewater: quantity and quality

Quality: variation mainly influenced by composition and quantity of industrial discharges

Quantity: variation influenced by water consumption, climate and state of sewerage network

Municipal wastewater: mixture



Municipal wastewater: key components

Suspended solids (SS) = particles suspended in the water

1. Particles can be organic or inorganic in nature
   - organic: remains of food, faeces, …
   - inorganic: fragments of plastic, sand from street runoff, …
2. Usually measured by filtration over a filter with pore size 0.45 µm
3. Impacts
   - Particles increase turbidity (water becomes less transparent) resulting in less light availability for plants
   - Organic particles can settle to the bottom and form a thick sediment layer in which anaerobic conditions will occur
   - Certain toxicants like pesticides and heavy metals are usually found adsorbed to these particles

Municipal wastewater: key components

Biodegradable organics

1. Usually expressed as BOD (Biochemical Oxygen Demand)

2. BOD is analysed by measuring O_2 consumption due to microbial activity over 5 days of a certain volume of wastewater stored in a airtight bottle under standard conditions (20 ºC, darkness)

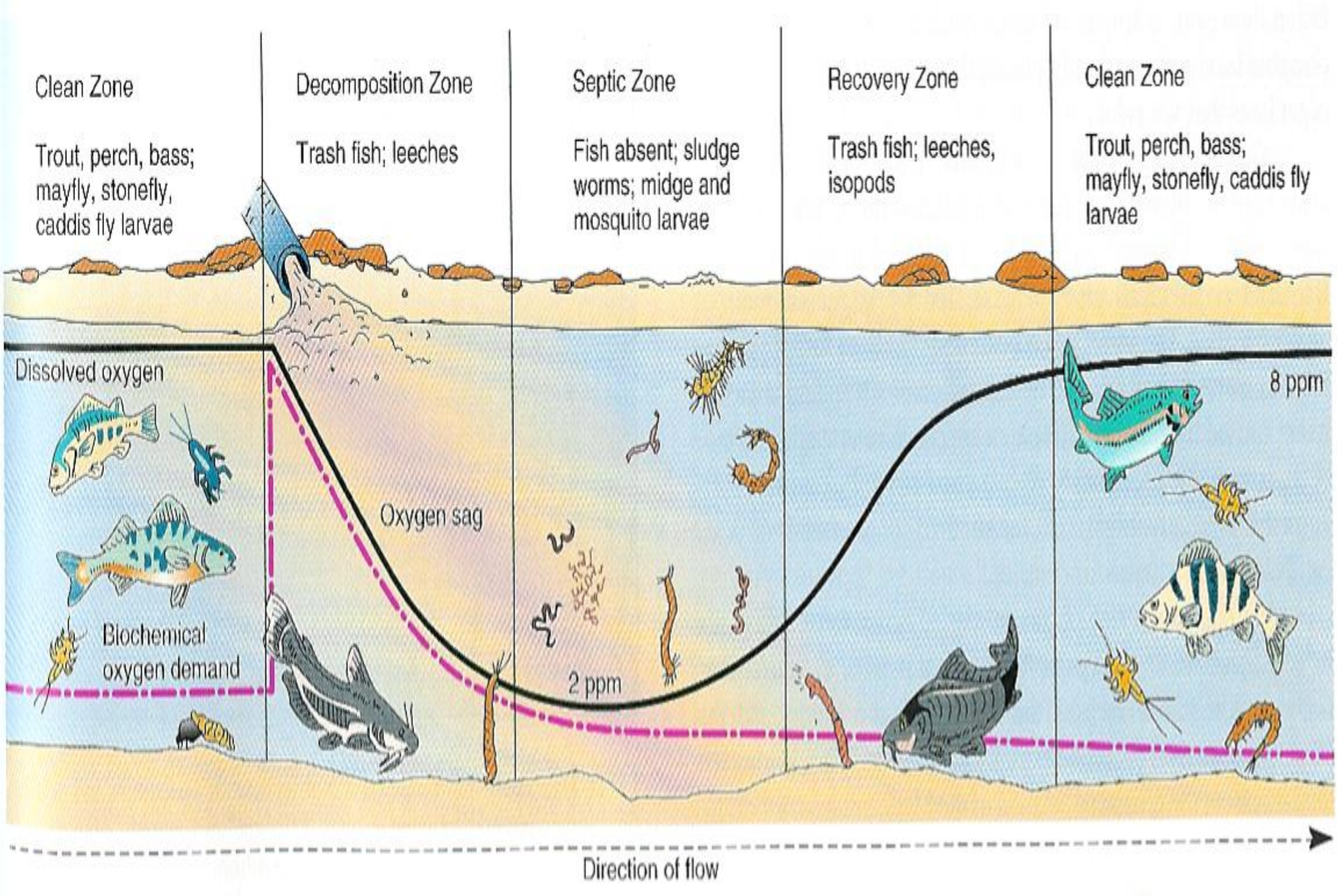
Example glucose: $C_6H_{12}O_6 + 6O_2 \rightarrow 6\ CO_2 + 6\ H_2O$

180 g 192g

➔ 1 g glucose ≈ 1.1 g oxygen demand

- Impacts: High BOD leads to anaerobic conditions
  → Lack of oxygen will kill aquatic life
  → Bad smells will occur (due to sulphide components etc.)

Effect of wastewater discharge on river organisms



Municipal wastewater: key components

Macronutrients: N and P

1. **Nitrogen** usually appears as organic nitrogen (proteins etc.) and as NH_4
   Phosphorus usually appears as organic phosphorus and as ortho-phosphate (dissolved PO_4)

2. Impacts: Increased primary production → algal blooms
   - Oxygen fluctuations (high during daytime because of photosynthesis, low during night because of respiration)
   - Extreme (alkaline) pH because of CO_2 consumption
   - Some algae produce toxins that cause fish kill
   - Algae outcompete water plants

Municipal wastewater: key components

Toxic compounds

1. Inorganic such as heavy metals
   Organic such as pesticides, antibiotics, detergents, …

2. Impacts:
   - **Acute toxicity** (immediate mortality) when occurring in very high concentrations
   - **Chronic toxicity** (sub-mortal effects noticeable only over longer period) when occurring in low concentrations
   - Danger for **bio-accumulation**: low concentrations in water → somewhat higher concentrations in algae → high concentrations in fish feeding on algae → lethal concentrations for mammals feeding on fish

Municipal wastewater: key components

Pathogens

1. Viruses, Bacteria, Protozoa, Helminths, …

2. Impacts: illnesses such as diarrhoea, Schistosomiasis, trachoma, …

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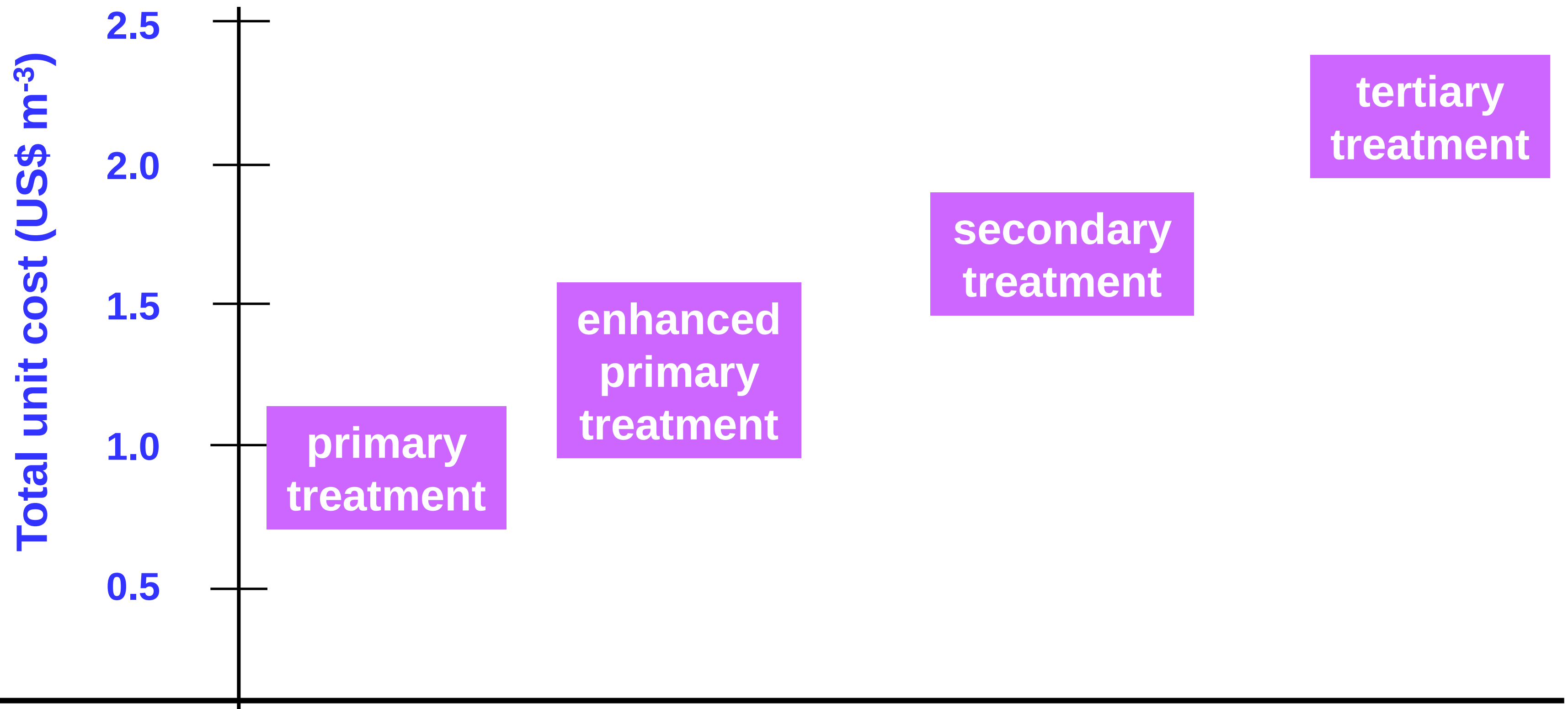
4. Important microbial processes
5. Important chemical processes

Degrees of treatment

	Removal of …	Technologies
Preliminary treatment	Coarse solids (cans, plastic bags, …)	Bar screens, Grit chambers
Primary treatment	Removal of fine particles (large food particles, …)	Primary clarifier
Enhanced primary treatment	Extra removal of particles by addition of chemicals	Coagulation/flocculation
Secondary treatment	Removal of organics (mostly dissolved BOD)	Activated sludge, Anaerobic treatment, …
Tertiary treatment	Removal of nutrients (N and P)	Activated sludge, Chemical precipitation, …
Disinfection	Pathogens	Ozonation, Chlorination, …

Costs and efficiency of various degrees of treatment



% removal				
BOD	30	50-70	90-95	> 95
TSS	60	80-90	90-95	> 95
N	15	25	40	> 80
P	15	75	90	> 90

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Physical processes: screening

Screens:

- spaces from 0.5 to 10 cm
- manual or automated removal of accumulated solids

Physical processes: settling or sedimentation

Particles settle to the bottom, velocity depends mainly on:

- particle diameter
- particle density

Circular settler (empty in the picture to show the internal structure)**:** Bridge travels around and pushes accumulated sludge to central evacuation pipe

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Microbial processes: aerobic carbon degradation

1. A group of micro-organisms, called “heterotrophs”, will degrade organic components in the presence of oxygen as follows:

   Example glucose: $C_6H_{12}O_6$ + **$6\ O_2$** → $6\ CO_2 + 6\ H_2O$

   Heterotrophs obtain energy from this process which enables them to reproduce.

2. Oxygen is usually provided via mechanical aeration.

3. Micro-organisms use dissolved BOD for this. When necessary, they can secrete enzymes which will convert particulate BOD into dissolved BOD (this process is called “hydrolysis”).

Microbial processes: denitrification

1. A group of micro-organisms, called "facultative heterotrophs", will degrade organic components in the absence of oxygen but the presence of nitrate as follows:

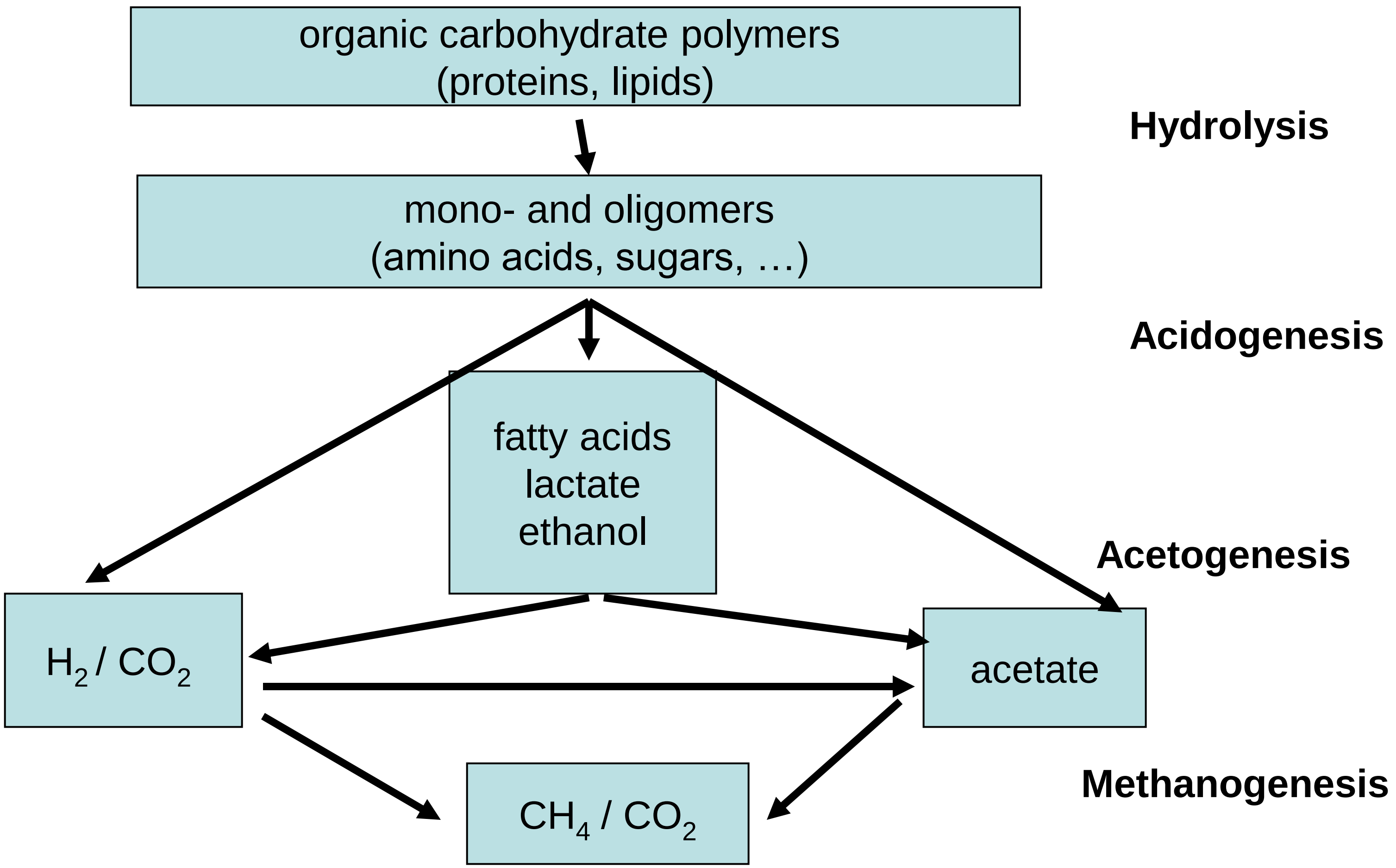
   $C_5H_{10}O_5$ + **$4NO_3^-$** + $4H^+ \rightarrow 5\ CO_2 + 7\ H_2O + 2\ N_2$

   Facultative heterotrophs obtain energy from this process which enables them to reproduce.

2. Hydrolysis can be done when needed.

Microbial processes: anaerobic carbon degradation

In the strict absence of oxygen and nitrate, following microbial processes can take place:



Microbial processes: nitrification

1. A group of micro-organisms, called "autotrophs", will convert ammonium into nitrate as follows:

   $NH_3 + O_2 \rightarrow NO_2^- + 3H^+ + 2e^-$
   $NO_2^- + H_2O \rightarrow NO_3^- + 2H^+ + 2e^-$

   Autotrophs obtain energy from this process which enables them to reproduce.

2. Oxygen is usually provided via mechanical aeration.

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Chemical processes: precipitation

Spontaneous precipitation: certain compounds have very low solubility products, resulting in an undissolvable fraction that will precipitate.

Example: $Fe^{2+} + S^{2-} \rightarrow FeS \downarrow$

Coagulation/flocculation: chemicals such as alum ($Al_2(SO_4)_3.14.3\ H_2O$), ferric chloride ($FeCl_3.6H_2O$), ferric sulfate ($Fe_2(SO_4)_3$), ferrous sulfate ($FeSO_4.7H_2O$) and lime ($Ca(OH)_2$) are often used to “build chemical bridges” between fine particles, thus creating larger particles that will more easily settle.

Chemical processes: adsorption

Adsorption is the accumulation of atoms or molecules on the surface of a material. This process creates a film of the adsorbate (the molecules or atoms being accumulated) on the adsorbent's surface.

Examples:

- adsorption of dissolved organic material to activated carbon
- adsorption of heavy metals to plant detritus