Quality of surface water

Explanation of the main parameters

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Introduction

Human activities have influenced the water quality of many surface waters all over India. Discharges from agricultural, industrial and most important urban areas have changed the chemical characteristics and additionally the ecological characteristics of water bodies.

In this presentation, a selection of the most important parameters for surface water quality and their role in the ecosystem will be discussed.

Oxygen

Oxygen plays a main part in water quality. It gets dissolved into water due to exchange with the air and the process of photosynthesis:

$$12H_2O + 6CO_2 + \text{light} \rightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$$

Plants and phytoplankton use sunlight as energy source to convert carbon dioxide and water to glucose and oxygen. This process strongly influences the oxygen concentration of the water. Especially on a sunny day, the oxygen concentration in aquatic systems increases significantly due to photosynthesis.

Next to photosynthesis, also respiration (the conversion of glucose to gain energy/ATP) takes place inside plants and algae:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy}$$

During the day, photosynthesis usually exceeds respiration. During the night, the oxygen concentration in aquatic systems decreases due to respiration.

Oxygen plays a major part in many other processes, of which some of them will be treated later in this presentation.

Biochemical Oxygen Demand

Biochemical Oxygen Demand (BOD) is the amount of oxygen that bacteria need for the degradation of organic matter:

$$(CH_2O)_n + \text{nutrient} + \text{bacteria} + O_2 \rightarrow$$

$$CO_2 + H_2O + \text{oxidized inorganic}$$

BOD is measured in a lab by taking and treating a water sample and incubate it in the dark for a specific time and under a specific temperature (usually 20°C for 5 days). The oxygen that is used during the 5 day incubation time, is called BOD_5.

The BOD_5 value is often applied to determine if a river is contaminated or if sewage water is effectively treated.

Uncontaminated rivers usually have a BOD_5 value of less than 1 mg/L. If a river is moderately contaminated, the BOD_5 value will be between 2 and 8 mg/L. Sewage water that is well cleaned can have a BOD_5 value around the 20 mg/L while untreated sewage water will have a BOD_5 value around 600 mg/L.

Chemical Oxygen Demand

Chemical Oxygen Demand (COD) is the amount of oxygen that is needed for both the breakdown of organic and inorganic material. Examples for the degradation of inorganic compounds are :

$$S^{2-} + 2O_2 \rightarrow SO_4^{2-}$$

$$NO_2^{-} + 1/2O_2 \rightarrow NO_3^{2-}$$

It is measured in a lab by taking and treating a water sample and incubate it in the dark for a specific time and under a specific temperature.

pH

pH is a dimensionless parameter of the activity of H^+ ions. It has a logarithmic scale and gives an indication of the acidity. pH values range between 1 and 14, in which 1 is very acid and 14 is very basic. Neutral waters have a pH of 7.

The opposite of pH is pOH. pOH is a value for the activity of OH^- ions. At a pH of 7, H^+ ions and OH^- ions are balanced. At low pH values, there is a high concentration of H^+ ions, while OH^- is apparent at high pH values.

The pH in surface waters varies, a peat area naturally has a low pH while the pH in limestone rich areas will be high.

The pH does not remain at a stable value during the whole day, but is influenced by activities of (micro)organisms. During photosynthesis, plants and algae use CO_2 which is a weak acid and turn it into O_2. This means that the pH of an aquatic system will rise during the day. At night the process is reversed and the pH will go down again due to the addition of CO_2.

However, in water contaminated with too much organic matter, the pH will not be influenced by photosynthesis. The high rate at which respiration is happening will create anaerobic circumstances and a lot of CO_2 will be produced, resulting in a low pH value.

pH also influences the solubility and bioavailability of nutrients and heavy metals. Heavy metals dissolve more easily in water with a low pH and become therefore more harmful for aquatic life.

Natural water usually have the ability to prevent the changes in pH that result from the addition of acids and bases. It’s called buffer capacity and is mostly due to dissolved limestone in the water ($CaCO_3$).

However, buffer capacity is not an inexhaustible feature of an aquatic system. If for example too much acid rain is added to the system, the pH will suddenly start to fall down rapidly. This often results in fish death and strong decline in biodiversity.

Dissolved Organic Carbon

Dissolved Organic Carbon (DOC) is a value for the total amount of carbon particles in the water that are smaller than 0.45 µm. It is used as an indicator for the organic loading of an aquatic system. DOC originates from different sources like degradation of plant material and algae in the water or from surface runoff from agricultural land. Also sewage effluent adds large amounts of DOC to aquatic systems. The carbon particles are used by bacteria as carbon and energy source. In this process they use oxygen and produce CO_2. A high DOC value therefore co-occurs with a high BOD, COD and a low pH.

An undisturbed aquatic system usually has a DOC value of 1.0 to 3.0 mg/L. This is with exception of systems like wetlands, swamps, peat areas and bogs. Those areas naturally have high DOC concentrations because of the large amount of decaying organic material.

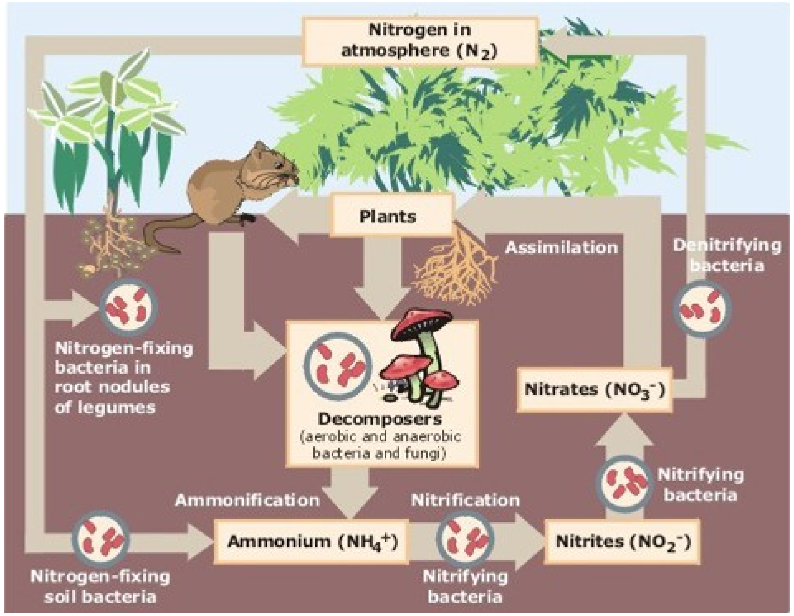
In the case of drinking water preparation, concentrations of DOC can contribute to the re-growth of bacteria after the water has been disinfected.

Nitrogen

Nitrogen or (N_2) is an essential nutrient that is used by plants for growth. The nutrient is not automatically available in the soil or in water, but is brought in there by lightning, blue-green algae or by bacteria that fix nitrogen from the atmosphere and turn it into ammonia (NH_3). Nitrifying bacteria use this substance to turn it into nitrite (NO_2^-) which is again turned into nitrate (NO_3^-). Ammonium and nitrate can be used by plants and algae for growth. The organisms are decomposed to ammonium again after they died.

Nitrate is also converted back into nitrogen again by denitrifying bacteria. The process is called denitrification and is described by the following formula:

$$NO_3^- + 10e^- + 12H^+ \rightarrow N_2 + 6H_2O$$



Denitrification only occurs under anaerobic conditions when the favorable electron acceptor oxygen is depleted, and in the presence of a suitable electron donor like organic material.

Source: MAIA

Phosphate

Phosphate (PO_4^{3-}) is another essential nutrient for plant life. It is mostly found on earth in the form of apatite which is a kind of mineral. Phosphate is usually not widely available in natural systems since weathering of rocks is a slow process.

Phosphate is one of the building block for DNA and RNA and is therefore needed by any living creature. Since it is not easily available, it is often a limiting nutrient for plant growth both in terrestrial as in aquatic systems. Therefore apatite is mined so that phosphate can be added to fertilizers.

Eutrophication

When land is used for agricultural purposes, the initial concentration of nitrate and phosphate in the soil is not enough for the intensive plant growth. Farmers therefore add fertilizer to increase the harvest or their corps. However, due to irrigation and rainwater, much of the nitrogen and phosphate is flushed away into the nearby creek, river, lake, etc. For aquatic plant and agae growth, both of the nutrients are also the limiting factor.

Eutrophication

Addition of extra fertilizer in the water will consequently result in lower water quality, excessive growth of plants, algae and reduction of biodiversity. This process is called eutrophication.

Excessive growth of plants often means that the water will be overgrown by one or a few plant species like duckweed. The plants outcompete the other species by for example preventing light to penetrate to the bottom. This process results in a decline in biodiversity and the ecological value of a system.

Eutrophication

High concentrations of algae in water have several consequences for the ecosystem. The algae in the first upper water layers will block all the light. Plants growing on the bottom can't survive in those circumstances and die.

During the day a lot of oxygen is produced by the algae. At night however, only the respiration process is happening and the oxygen gets depleted. Fish as well as other aquatic animals need dissolved oxygen in the water and will suffocate if the water becomes hypoxic.

Eutrophication

There is usually a combination of different kinds of algae in water, like red algae, green algae and blue-green algae (cyanobacteria).

The higher the nutrient loading in the water, the higher the algae concentration. At this point, light becomes the limiting factor for algae growth. Blue-green algae have in this case the highest advantage since they are the most efficient in the use of light and become the dominating species. (Although there are more ways at which algae compete)

Some species of blue-green algae can be eaten, but a lot of them produce toxins. This toxin is used to prohibit the growth of other algae and plants. The toxin is also very dangerous for fish, birds, animals and humans. Cattle that dinks from water contaminated with lots of blue-green algae can get very sick. Toxins from algae can also work their way op in the food chain. Toxins that are taken up by for example shellfish or fish that are caught for consumption can pose a treat for humans.

Nitrate in the water directly poses a treat to babies. It happens when nitrate from the surface water seeps into the groundwater or if surface water is used for consumption. In the body, nitrate gets converted into nitrite. Nitrite reacts with hemoglobin to form a substance called methemoglobin. Methemoglobin is not capable of carrying oxygen and the baby will finally suffocate.

Salinity

The salinity of the water is the relative concentration of all the different salts in a solution. It is often measured in electro conductivity: µS/m and µS/cm. Salinity can also be expressed as parts per thousand (0/00), parts per million (ppm) or milligrams per litres (mg/L) of chlorine (Cl). (mg/L is the same as ppm)

Salt concentrations in water are usually divided in the following way:

Salt:	**10 000 mg/L**	**Light brackish:**	**200 -1 000 mg/L**
Brackish:	**1 000 - 10 000 mg/L**	**Fresh:**	**0 - 200 mg/L**

There are two major problems caused by dissolved salts in water. The first is that soils can become saline after the use of water for irrigation. Even fresh water contains a small amount of salts. When that water is used for irrigation, the water will be taken up by the plants or will be evaporated while the salt stays behind. When there are no periods with enough heavy rainfall to flush the salt away, the soil eventually gets too saline for agriculture.

Another problem with saline water is caused by the use of groundwater in coastal areas. The fresh groundwater in those areas is floating on a layer of saline sea water. When the fresh water is used for drinking water or irrigation, the salt water will rise until eventually the wells will become completely salt. Solving this problem means that the uptake of fresh water has to be stopped and that new fresh water has to be infiltrated in order to push the salt water down again. However, lack of fresh water makes this solution difficult to accomplish.

References

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