BASICS OF WASTEWATER TREATMENT

Knowing the decisioning criteria relevant to site and drain field suitability, i.e., soil properties, can be enhanced by an understanding of some of the basics of wastewater treatment. You will see terms like BOD, total suspended solids, nitrification, and denitrification frequently when discussing wastewater treatment. It is important to understand what each of these terms mean and how each relates to the wastewater treatment process.

BASIC CONSTITUENTS OF WASTEWATER

Biochemical oxygen demand

One of the most commonly measured constituents of wastewater is the **biochemical oxygen demand, or BOD**. Wastewater is composed of a variety of inorganic and organic substances. Organic substances refer to molecules that are based on carbon and include fecal matter as well as detergents, soaps, fats, greases and food particles (especially where garbage grinders are used). These large organic molecules are easily decomposed by bacteria in the septic system. However, oxygen is required for this process of breaking large molecules into smaller molecules and eventually into carbon dioxide and water. The amount of oxygen required for this process is known as the biochemical oxygen demand or BOD. The Five-day BOD, or BOD_5, is measured by the quantity of oxygen consumed by microorganisms during a five-day period, and is the most common measure of the amount of biodegradable organic material in, or strength of, sewage.Sewage high in BOD can deplete oxygen in receiving waters, causing fish kills and ecosystem changes.

However, BOD content of sewage is also important for septic systems. Sewage treatment in the septic tank is an anaerobic (without oxygen) process; in fact, it is anaerobic because sewage entering the tank is so high in BOD that any oxygen present in the sewage is rapidly consumed. Some BOD is removed in the septic tank by anaerobic digestion and by solids which settle to the bottom of the septic tank, but much of the BOD present in sewage (especially detergents and oils) flows to the leaching field. Because BOD serves as a food source for microbes, BOD supports the growth of the microbial biomat which forms under the leaching field. This is both good and bad. On the one hand, a healthy biomat is desired because it is capable of removing many of the bacteria and viruses in the sewage so that they do not pass to the groundwater. The bacteria in a healthy biomat also digest most of the remaining BOD in the sewage. Too much BOD, however, can cause excessive growth of bacteria in the biomat. If the BOD is so high that all available oxygen is consumed (or if the leaching field is poorly aerated, as can be the case in an unvented leaching field located under pavement or deeply buried) the biomat can go anaerobic. This causes the desirable bacteria and protozoans in the biomat to die, resulting in diminished treatment of the sewage. Low oxygen in the biomat also encourages the growth of anaerobic bacteria (bacteria which do not require oxygen for growth). Many anaerobic bacteria produce a mucilaginous coating which can quickly clog the leaching field. Thus, excess BOD in sewage can cause a leaching field to function poorly and even to fail prematurely.

BOD removal can be especially important where sewage effluent flows to a leaching field in tight soils. Tight soils are usually composed of silts and clays (particle size < 0.05 millimeter). These small soil particles are tightly packed and the pore space between them is small. Reducing BOD means that the sewage will support the growth of less bacteria and therefore the effluent will be better able to infiltrate tight soils. Many enhanced treatment technologies that remove BOD were designed specifically to enhance disposal of effluent in tight silt or clay soils.

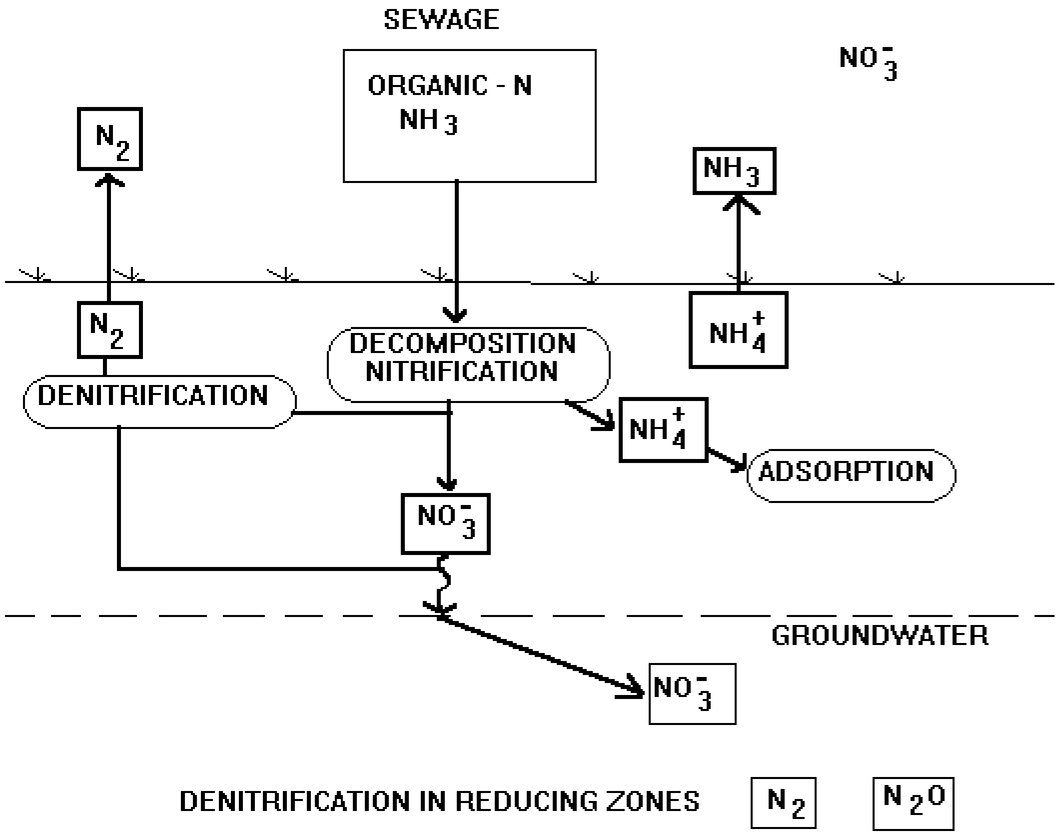
BOD is fairly easy to remove from sewage by providing a supply of oxygen during the treatment process; the oxygen supports bacterial growth which breaks down the organic BOD. Most enhanced treatment units incorporate some type of unit which actively oxygenates the sewage to reduce BOD. This unit is often located between the septic tank and the leach field. Or, it can be located within the septic tank in a specific area where oxygen is supplied. Reduction of BOD is a relatively easy and efficient process, and results in sewage of low BOD flowing to the leaching field. It is important to note, however, that low BOD in sewage may result in a less effective biomat forming under the leaching field.

It is also important to note that BOD serves as the food source for the denitrifying bacteria which are needed in systems where bacterially-mediated nitrogen removal takes place. In these situations BOD is desired, as the nitrification/denitrification process cannot operate efficiently without sufficient BOD to support the growth of the bacteria which accomplish the process.

Total suspended solids

Domestic wastewater usually contains large quantities of suspended solids that are organic and inorganic in nature. These solids are measured as **Total Suspended Solids or TSS** and are expressed as mg TSS/ liter of water. This suspended material is objectionable primarily because it can be carried with the wastewater to the leachfield. Because most suspended solids are small particles, they have the ability to clog the small pore spaces between soil grains in the leaching facility. There are several ways to reduce TSS in wastewater. The simplest is the use of a septic tank effluent filter. This type of filter fits on the outlet tee of the septic tank. It is made of PVC with various size slots fitted inside one another. The filter prevents passage of floating matter out of the septic tank and, as effluent filters through the slots, fine particles are also caught. Many types of alternative systems are also able to reduce TSS, usually by the use of settling compartments and/or filters using sand or other media.

Total nitrogen



Nitrogen is present in many forms in the septic system. Most nitrogen excreted by humans is in the form of organic nitrogen (dead cell material, proteins, amino acids) and urea. After entering the septic tank, this organic nitrogen is broken down fairly rapidly and completely to ammonia, NH_3, by microorganisms in the septic tank. Ammonia is the primary form of nitrogen leaving the septic tank. In the presence of oxygen, bacteria will break ammonia down to nitrate, NO_3. In a conventional septic system with a well aerated leaching facility, it is likely that most ammonia is broken down to nitrate beneath the leaching field.

Nitrate can have serious health effects when it enters drinking water wells and is consumed. Nitrate and other forms of nitrogen can also have deleterious effects on the environment, especially in coastal areas where excess nitrogen stimulates the process known as eutrophication. For this reason, many alternative technologies have been designed to remove total nitrogen from wastewater. These technologies use bacteria to convert ammonia and nitrate to gaseous nitrogen, N_2. In this form nitrogen is inert and is released to the air.

Biological conversion of ammonia to nitrogen gas is a two step process. Ammonia must first be oxidized to nitrate; nitrate is then reduced to nitrogen gas. These reactions require different environments and are often carried out in separate areas in the wastewater treatment system.

The first step in the process, conversion of ammonia to nitrite and then to nitrate, is called nitrification ($NH_3 \rightarrow NO_2$ NO_3). The process is summarized in the following equations:

$$NH_4 + 3/2\ O_2 \rightarrow NO_2^- + 2H^+ + H_2O$$

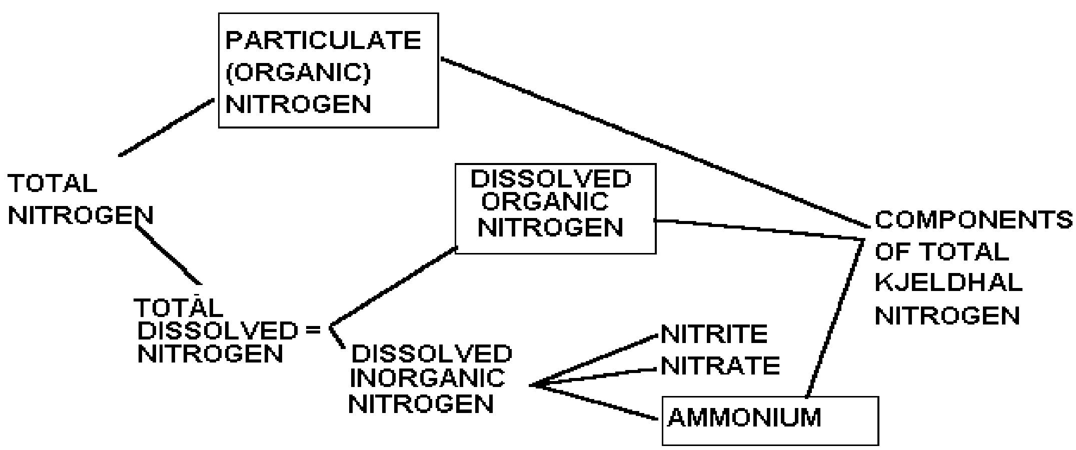
$$NO_2^- + 1/2\ O \rightarrow NO_3^-$$

It is important to note that this process requires and consumes oxygen. This contributes to the BOD or biochemical oxygen demand of the sewage. The process is mediated by the bacteria *Nitrosomonas* and *Nitrobacter* which require an aerobic (presence of oxygen) environment for growth and metabolism of nitrogen. Thus, **the nitrification process must proceed under aerobic conditions.**

The second step of the process, the conversion of nitrate to nitrogen gas, is referred to as **denitrification**. This process can be summarized as:

$$NO_3^- + 5/6\ CH_3OH \rightarrow 1/2\ N_2 + 5/6\ CO_2 + 7/6\ H_2O + OH^-$$

This process is also mediated by bacteria. For the reduction of nitrate to nitrogen gas to occur, the dissolved oxygen level must be at or near zero; the denitrification process must proceed under anaerobic conditions. The bacteria also require a carbon food source for energy and conversion of nitrogen. The bacteria metabolize the carbonaceous material or BOD in the wastewater as this food source, metabolizing it to carbon dioxide. This in turn reduces the BOD of the sewage, which is desirable. However, if the sewage is already low in BOD, the carbon food source will be insufficient for bacterial growth and denitrification will not proceed efficiently.



Clearly, any wastewater treatment unit that is going to remove nitrogen by the nitrification/denitrification process must be designed to provide both aerobic and anaerobic areas so that both nitrification and denitrification can proceed.

Phosphorus

Phosphorus is a constituent of human wastewater, averaging around 10 mg/liter in most cases. The principal forms are organically bound phosphorus, polyphosphates, and orthophosphates. Organically bound phosphorus originates from body and food waste and, upon biological decomposition of these solids, is converted to orthophosphates. Polyphosphates are used in synthetic detergents, and used to contribute as much as one-half of the total phosphates in wastewater. Many places have banned the sale of phosphate-containing clothes washing detergent, so phosphorus levels in household wastewater have been reduced significantly from previous levels. Most household phosphate inputs now come from human waste and automatic dishwasher detergent. Polyphosphates can be hydrolyzed to orthophosphates. Thus, the principal form of phosphorus in wastewater is assumed to be orthophosphates, although the other forms may exist. Orthophosphates consist of the negative ions PO_4^{3-}, HPO_4^{2-}, and $H_2PO_4^-$. These may form chemical combinations with cations (positively charged ions).

It is unknown how much phosphorus is removed in a conventional septic system. Some phosphorus may be taken up by the microorganisms in the septic system and converted to biomass (of course, when these microorganisms die the phosphorus is re-released, so there really is no net loss of phosphorus by this mechanism). Any phosphorus which is not removed in the septic system probably is removed under the leaching facility by chemical precipitation.

At slightly acidic pH (< 7.0), orthophosphates combine with tri-valent iron or aluminum cations to form the insoluble precipitates $FePO_4$ and $AlPO_4$.

$$Fe^{3+} + (H_nPO_4)^{(3-n)} \longrightarrow FePO_4 + nH^+$$

$$Al^{3+} + (H_nPO_4)^{(3-n)} \longrightarrow AlPO_4 + nH^+$$

Under alkaline conditions, in the presence of calcium, phosphorus combines with calcium to form insoluble apatite, i.e., rock phosphate.

One caveat must be added here. If the soil below the leaching facility becomes anaerobic, iron may become chemically reduced (changed to the Fe^{2+} form), which is soluble and able to travel in groundwater. In this case, the iron phosphate compounds may breakdown and phosphorus may also become soluble. Anaerobic conditions under the leaching facility can occur when the leaching facility is not well aerated, when there is a small vertical separation to groundwater, or when BOD in the sewage is so high that all oxygen present is depleted to oxidize BOD. The best method for maximizing phosphorus removal is probably to locate the leaching facility well above groundwater (>5 feet vertical separation above groundwater) thereby providing a well-aerated area under the leaching field. To date, no alternative on-site technologies are capable of significant phosphorus removal.

References

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