TERTIARY TREATMENT

Tertiary treatment of wastewater is any process that occurs after secondary treatment. It can be polishing processes that improve suspended solids removal or nutrient removal processes. Nutrient removal is includes processes like nitrification/denitrification, ammonia stripping, phosphorous precipitation, and land application or overland flow.

EFFLUENT POLISHING

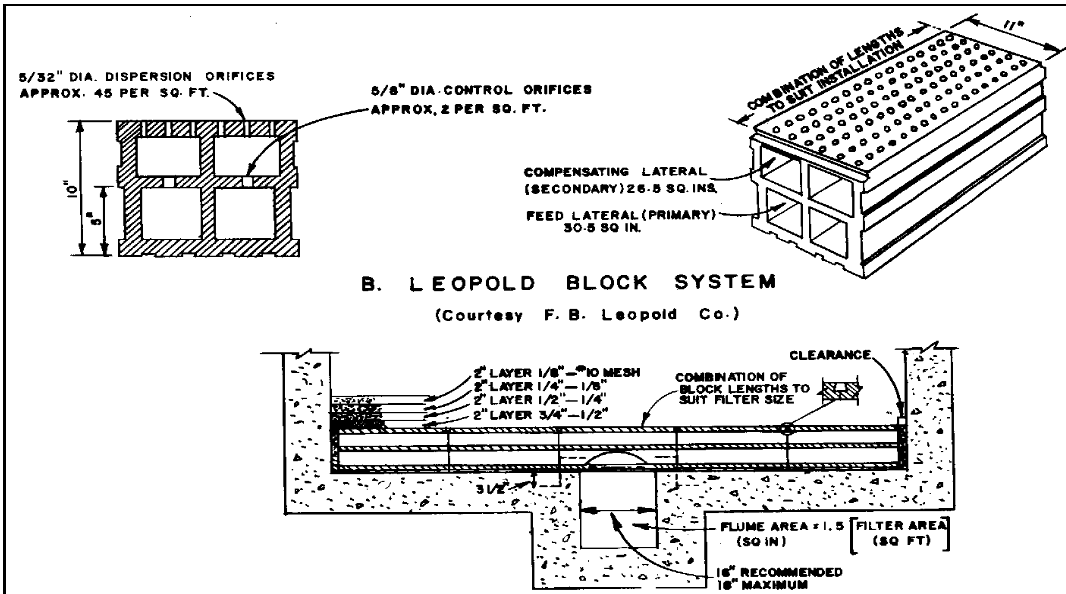
Effluent polishing is a physical treatment process. Effluent polishing is normally accomplished filtration of secondary effluent in an effort to remove suspended solids from ashing or pin floc problems. These filters are similar to those used to treat drinking water.

RAPID SAND FILTERS

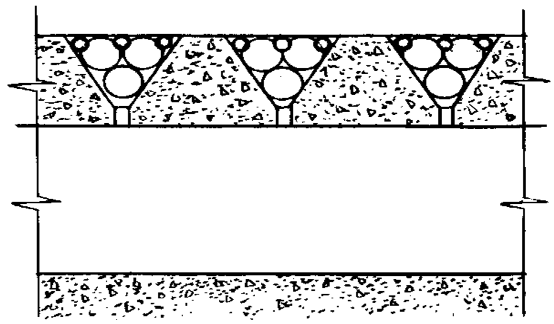
Conventional rapid sand and mixed media filters have many design similarities. The basic components of the filters include all of the components described below. The main differences will be in the type of media that is used and the valving configurations.

Filter boxes may be constructed as rectangles, squares, round, or as the outer segment of a ring. A filter box is approximately ten feet deep, though its surface dimensions may vary depending on the volume of water to be filtered.

The **underdrain** serves three basic functions. Although it supports the filter media and collects the filtered water, its most important function is to evenly distribute the backwash water throughout the filter. Leopold tile and Wheeler blocks are two popular types of underdrain systems



FILTER UNDERDRAIN SYSTEM

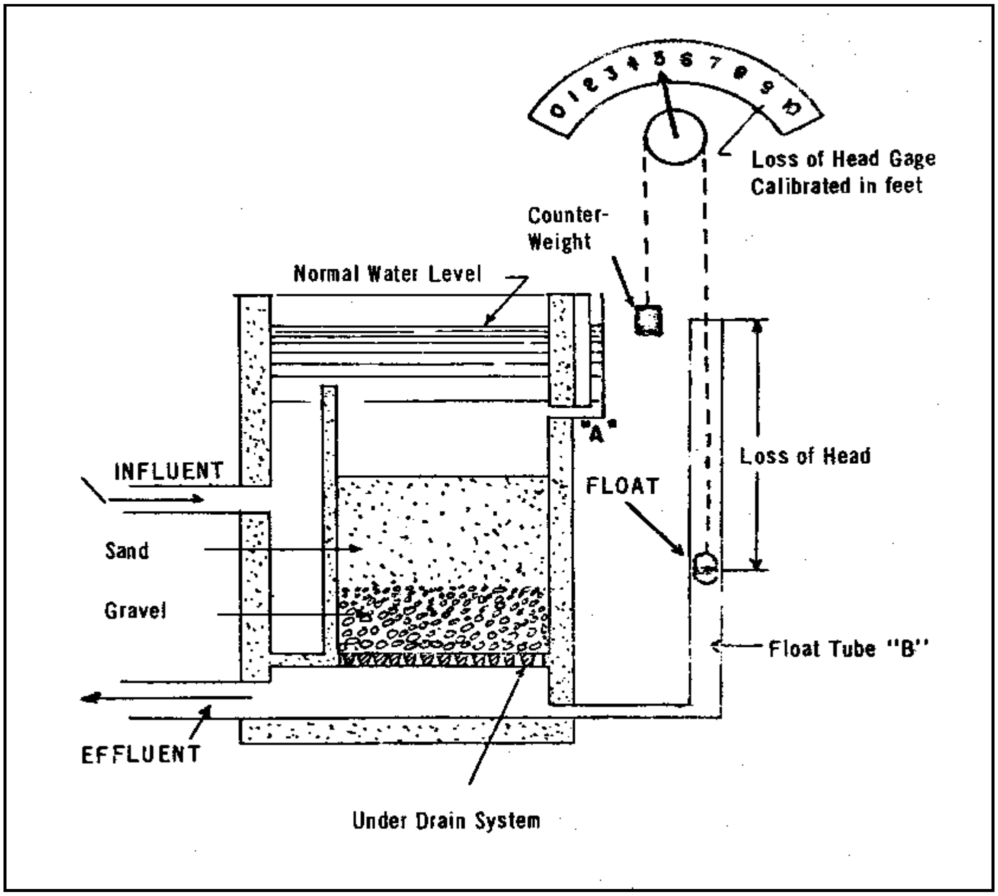


Filter media consists of sand, gravel, and small rocks of varying sizes. Six to eight inches of small rock is placed on top of the filter underdrain. A layer of pea gravel is placed on top of the rocks, usually three to six inches in depth, followed by layer of gravel of increasingly smaller size. This material will support the sand and keep it away from the underdrain. The actual filter media is a layer of medium size sand about 24 inches in depth. This sand should be sized so that the grains are between 0.3 to 0.6 millimeters in diameter. The uniformity coefficient for the sand media should be at least 0.9. This means that 90% of the grains will fall within the 0.3-0.6 mm range.

The **rate of flow controller** maintains a constant flow of water throughout the filter run. As the filter media becomes clogged the rate of flow controller opens a valve on the effluent line that compensates for the head loss through the filter. When the head loss reaches 8 feet, the rate of flow controller is fully open. The proper flow rate for a rapid sand filter is 2 gpm/sqft. Dual media filters run at 3-5 gpm/sqft. Multi-media filters operate at 5-8 gpm/sqft.

Loss of head gauge indicates when the filter is in need of backwashing. The loss of head is determined by the difference between the level of water in the filter and the level of a column of water that represents the pressure in the effluent line. This is referred to as the feet of head loss through the sand bed. When the head loss reaches 8 feet the filter should be backwashed.

Five **valves** are needed to properly operate a filter. The "influent" and "effluent" valves are open during normal operation and closed during backwash. The "backwash valve" provides a means for cleaning the filter and the "waste valve" allows the backwash water to leave the filter. A fifth valve, the “surface wash valve”, is also used when surface washers are installed. Surface washers of some type will usually be found on all new filter installations.

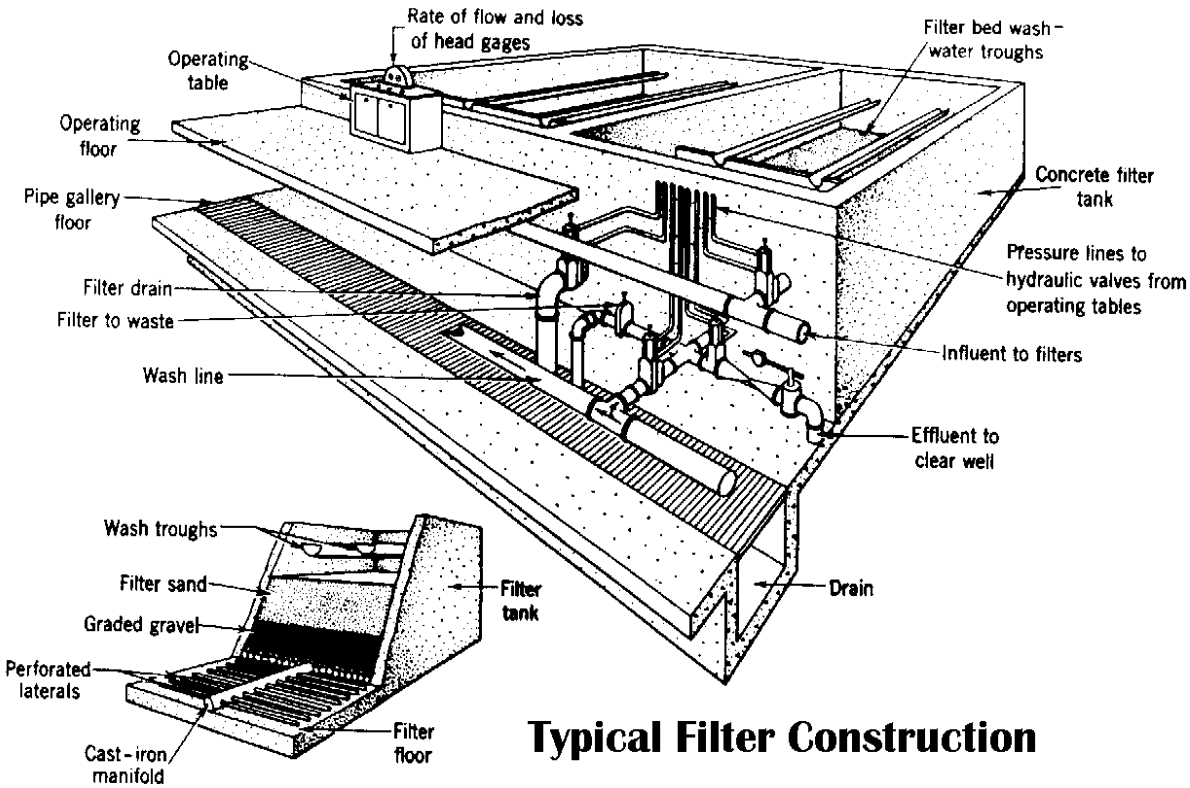


Loss of Head Gauge

Backwash troughs collect the backwash water and transport it out of the filter. These troughs should be no farther than six feet apart and the rim of the trough should be 24-28 inches above the filter media. This is known as the freeboard of the filter. In filters that use anthracite coal in the media, the freeboard should be 32-36 inches to prevent loss of media during backwash.

Surface washers are used during the backwash cycle to agitate and break up the top layer of the sand where most of the dirt is trapped. This step helps reduce the amount of backwash water needed for a filter by reducing the time it takes to properly clean the filter.

A **backwash pump** or tower is used to supply the backwash water to the filter. It must be capable of supplying at least 15 gpm/sq. ft. of filter area. Enough backwash water must be available to run the backwash for 7-15 minutes on average. The backwash water will be treated effluent in a wastewater plant. The backwash water is usually sent to an equalization basin and then back to the headworks of the plant. If the backwash rate is too low, the media will develop "mudballs". If it is too high, media may be blown out of the filter.



Typical Filter Construction

EFFLUENT POLISHING PONDS

Effluent polishing ponds are shallow aerobic lagoons that receive treated secondary effluent. They are sometimes mechanically aerated. The non-aerated ponds will stay aerobic because there shouldn't be much BOD left to create an oxygen demand. Usually wind action and surface oxygen transfer will provide adequate aeration since the ponds are only 2-3 feet deep. They provide a final chance to remove suspended solids and lower the effluent BOD. They may also provide the detention time and U-V radiation from sunlight to naturally dechlorinate the effluent after disinfection.

NUTRIENT REMOVAL

The first goal of wastewater treatment is to remove suspended solids and BOD. Suspended solids created sediment in the receiving waters and organics will continue to decompose, using up oxygen that the aquatic wildlife needs. There is another problem that affects aquatic wildlife and directly impacts the water quality of the receiving waters. Nitrogen and phosphorous compounds in the wastewater effluent can be toxic to fish, as is the case with ammonia, and can act as natural fertilizers that increase the growth rate of aquatic plants like algae. This can result in algae blooms that can choke out other aquatic life in the lake or river. The nitrogen cycle that occurs, as ammonia is oxidized to nitrates, also results in a reduction of dissolved oxygen (DO) in the receiving waters.

The first treatment processes that dealt with the nitrogen issue were nitrification processes. The intent was to convert the ammonia present in the secondary processes to nitrates. This would create a more stable form of nitrogen and minimize the oxygen depletion that would occur in the river. But the nitrates still acted as an aquatic fertilizer that created algae problems. Denitrification processes were developed to convert nitrates to elemental nitrogen gas that can be stripped from the effluent by aeration.

NITRIFICATION

Nitrification of wastewater will occur after most of the BOD has been removed. If enough dissolved oxygen is available, nitrifying bacteria like *Nitrobacter* and *Nitrosomonas* will begin oxidizing ammonia (NH_3) into nitrites (NO_2) first and then nitrates (NO_3).

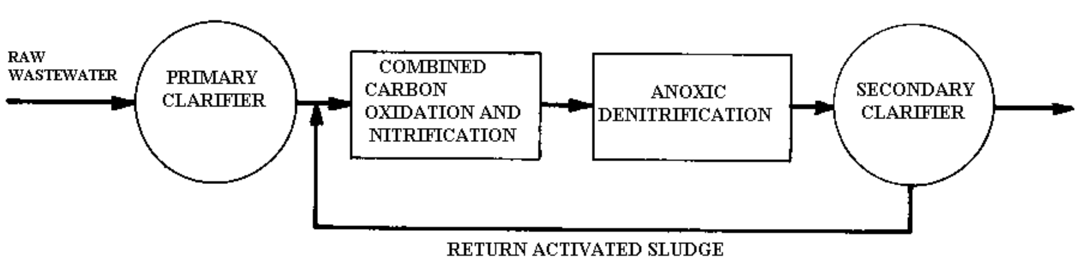
This process requires a tremendous amount of oxygen. It takes 4-5 pounds of oxygen to convert one pound of ammonia to nitrates. Dissolved oxygen levels need to be in the 4-6 mg/L range to accomplish nitrification. Alkalinity is also removed during this process. About 7 pounds of alkalinity will be consumed to oxidize one pound of nitrogen. Nitrification usually occurs in the latter stages of multi-staged activated sludge systems and extended aeration systems. The long detention times give the bugs time to oxidize the BOD and then oxidize the ammonia to nitrates. Multi-staged RBC processes can also nitrify if they are aerated to maintain the higher DO levels.

DENITRIFICATION

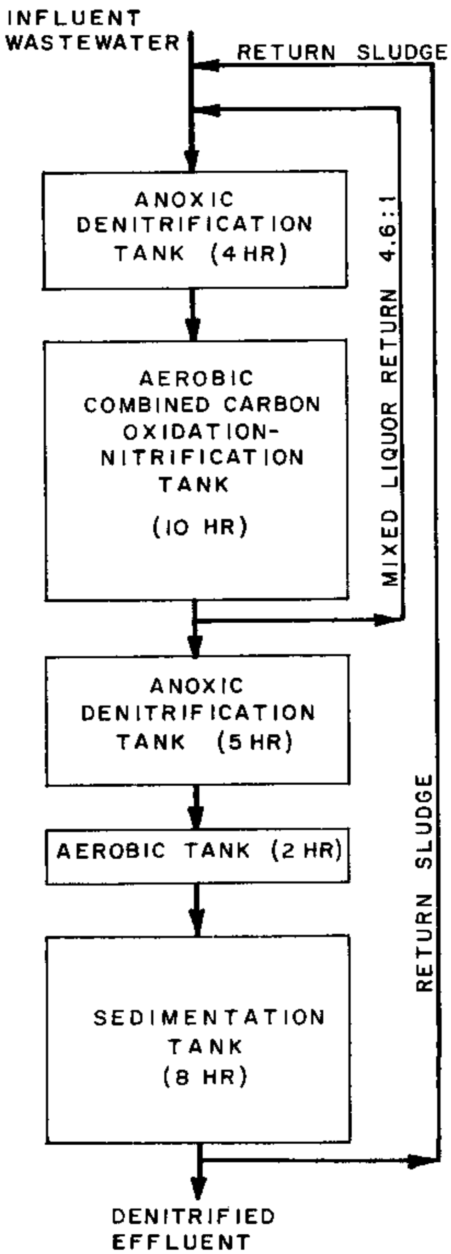
The most common process used to remove the nitrogen completely is known as denitrification. It follows the nitrification process. It utilizes denitrifying bacteria to remove the oxygen from the nitrate compounds. Nitrates are converted into nitrogen gas (N_2), which effectively removes the nitrogen from the waste flow.

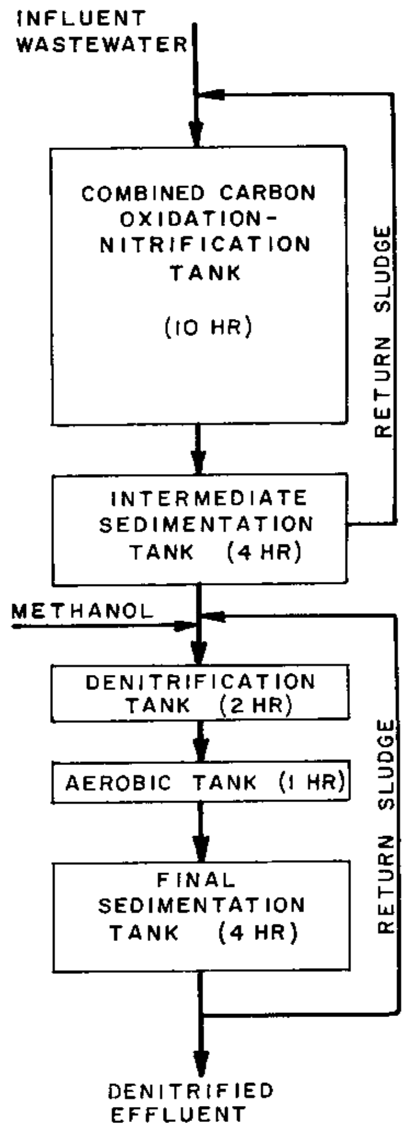
All bacteria need oxygen for respiration. The aerobic bacteria get their oxygen for dissolved oxygen (O_2) in the water. The anaerobic and facultative bacteria still need oxygen too. When no DO is present, they get oxygen from stripping oxygen from sugars, starches, and sulfates (releasing CO_2, CH_4, and H_2S in the process). Denitrifying bacteria are facultative and can use oxygen from nitrates. In order for them to use this chemically bound oxygen, the DO must be less than 0.1 mg/L. This is known as an anoxic condition. Anoxia is the chemical equivalent of anaerobic biological conditions.

COMBINED CARBON OXIDATION-NITRIFICATION-DENTRIFICATION



The denitrification process follows nitrification. The dissolved oxygen level leaving the nitrification process is usually 4-6 mg/L. This DO must be removed quickly so that denitrification can begin. Some denitrification processes rely on the addition of a carbon source, like methanol, that facultative bacteria can use to burn up the remaining dissolved oxygen. Once this accomplished, the denitrifying organisms will begin to use the oxygen in the nitrates for respiration. The nitrogen gas that is released in the process is removed by aeration prior to final clarification. This is a gas stripping process that causes the water to give up nitrogen gas as it absorbs the oxygen. The effluent DO levels should be brought back up to 2.0 mg/L.





Bardenpho Denitrification Process **Methanol Denitrification Process**

Denitrification Basin
Anoxic Stage

Denitrification Basin
Final Aeration Stage

The two most common denitrification processes are the Bardenpho and the methanol processes. The Bardenpho process uses an anoxic basin followed by a standard BOD/nitrification process, but no clarification. Mixed liquor is returned to the front of the process instead of RAS. Another extended anoxic basin is used to reduce the dissolved oxygen and create denitrification. The effluent passes to an aeration basin where the gas stripping process occurs and then to clarifiers. The RAS is returned to the head of the process. The main disadvantage of the Bardenpho process is the extended detention time in the two anoxic processes.

A standard activated sludge nitrification process with intermediate clarification precedes the methanol denitrification process. The methanol addition allows the bacteria to burn up the remaining dissolved oxygen very quickly. The denitrification stage is accomplished in about two hours followed by a one-hour aeration cycle for gas stripping. The RAS is returned to the front of the denitrification basin instead of the head of the plant.

Denitrification can occur in most activated sludge processes. The problem is that it usually occurs in the clarifiers. This can cause rising sludge problems. The situation is similar to what happens in the primary clarifiers when sludge sits in the tank too long and goes septic. The release gases from the decomposition causes the sludge to rise. The main difference is that the gas that floats the secondary sludge is nitrogen gas. That is why there is not normally much odor associated with rising secondary sludge.

Denitrification may also occur in some oxidation ditch processes. An oxidation ditch only has one or two points (the rotor brushes) where DO is added to the process. As the mixed liquor moves around the basin, the DO is used up and anoxic conditions may be created on the backside of the oval ditch. This anoxic zone can promote denitrification.

OTHER NITROGEN REMOVAL PROCESSES

Other methods of removing nitrogen from wastewater include ammonia stripping towers, water hyacinth lagoons, land application/overland flow, chemical oxidation, and ion exchange. Gas stripping to remove ammonia is a physical treatment process that takes advantage of two of the laws regarding the relationship between gases and water. First, there is a limit to the amount of dissolved gas that water can hold. The limit varies with changes in temperature or pressure of the water. Second, water prefers dissolved oxygen to other dissolved gasses like carbon dioxide (CO_2), hydrogen sulfide (H_2S), or ammonia (NH_3). If DO is available, water will absorb the oxygen and release the other gasses to atmosphere. The stripping tower (sometimes looking like a fountain) will provide the aeration that allows this to happen. There is one major drawback to the ammonia stripping process. The pH of the water must be in the 10.5-11.0 range. This exceeds regulator limit and will require a pH adjustment to get up to 10.5 and another pH adjustment back down to below 9.0 afterwards. This creates a physical/chemical treatment process that will require more frequent operator attention and the use of chemical storage and feed equipment.

Water hyacinth plant is a form of aquatic vegetation that has an amazing ability to remove pollutants from water. Ponds containing hyacinth plants have been used to remove any number of heavy metal pollutants in some industrial applications. The hyacinth's growth rate causes plant mass to double every 2-3 weeks. In the process, it soaks up a huge amount of nitrogen. The problem with hyacinth operations is that a portion of the plants must be harvested several times a year. Disposal options include composting or landfill. If used for heavy metal removal landfilling may not an option. Also, some states will not allow the importation of hyacinth plants due to concerns that they will spread to receiving streams and lakes.

Land application of the plant effluent for irrigation is another alternative that has become more popular as water reuse has increased over the years. One of factor that might limit the amount of application would be nitrate nitrogen migrating into groundwater supplies. Effluent applied to public recreational areas must be disinfected. Overland flow systems are designed for retrieval and discharge of the effluent instead of an irrigation project that has no discharge to a receiving stream. A clay and loam soil is graded to a 1-1.5% downhill grade. The clay soil needed for overland flow projects limits the amount of groundwater intrusion. It is seeded with a grass that has a high nitrogen uptake like rye or alfalfa. Treated effluent is allowed to run down the slope where it is collected in a channel at the bottom. As the grasses fill in the area, they impede the flow of water and give the plants and microorganisms in the soil a chance to absorb the nitrogen. The plants will soak up some of the flow and there will be some evaporation during the process, so the discharge flow will also be lowered. The nitrogen is removed from the process by harvesting the crop.

Chemical oxidation of ammonia with chlorine is possible. But it takes a lot of chlorine (10:1 ratio) to accomplish this. This will also increase the cost of dechlorination. Ion exchange resin beds can also be used to remove nitrogen.

PHOSPHOROUS REMOVAL

Phosphorus removal is also a chemical process. Phosphorous can be precipitated as a floc particle using the same type of process that surface water systems use for softening drinking water. Alum or lime can be used as the coagulant. The treatment equipment will include a tertiary flocculation and sedimentation process and effluent filtration.

Advanced Study Questions

1. Why is the filter backwash rate important?

2. What are the different options for removing nitrogen from wastewater?

3. What is the difference between overland flow and irrigation?

4. What is the problem associated with ammonia stripping?

5. Which two chemicals can be used to precipitate phosphorous?

Advanced Sample Test Questions

1. Ammonia discharged to the receiving stream is a problem because:

   A. Ammonia is toxic to fish
   B. Natural oxidation will remove DO from the stream
   C. It will increase algae growth
   D. All of the above

2. Which bacteria are not responsible for nitrification?

   A. Nitrobacter
   B. Nocardia
   C. E. Coli
   D. They all nitrify

3. If chlorine is used to oxidize ammonia the ratio will need to be:

   A. 2:1
   B. 5:1
   C. 7:1
   D. 10:1

4. For denitrification to occur, the conditions must be:

   A. Aerobic
   B. Anoxic
   C. Anaerobic
   D. Facultative

5. For nitrification, the dissolved oxygen requirement is about:

   A. 2 pounds per pound of nitrogen
   B. 4 pounds per pound of nitrogen
   C. 6 pounds per pound of nitrogen
   D. 8 pounds per pound of nitrogen