Chapter 12: Tertiary Treatment

Tertiary treatment is the name given to processes designed to remove various pollutants from the wastewater stream other than the common BOD, and TSS. The two main subjects covered under tertiary treatment are Phosphorus removal and Nitrification and Denitrification. In addition Wetlands processes as a tertiary treatment process will also be covered here.

Constructed Wetlands

Constructed wetlands are the name given to a process designed to provide small scale wastewater treatment. The focus of wetlands has been the need to remove nitrogen from the waste stream. Biologically, constructed wetlands operate much the same way as natural wetland processes.

Theory of Operation

Constructed wetlands operate by using wetland plants to up take the nutrients in the wastewater. In theory they were expected to nitrify and denitrify wastewater using a combination of microbiological growth and aquatic plants. Typical plants include Bulrushes and Cattails.

Constructed wetlands come in many forms including Subsurface flow, and overland or ponds. The main difference between these two is whether the wastewater is allowed to surface and be acted on by the sun and wind.

In Subsurface flow (also known as reed beds) the wastewater is distributed via a system of pipes below the surface in a bed of gravel or pumice. This type of system operates much like a trickling filter in that a microbiological colony is established to remove the nutrients from the wastewater. These units' are often found in conjunction with septic tanks. The septic tanks were to remove settleable solids which would cause clogging of the media and force the water to the surface. Often found lacking in the design of the systems is an adequate method for removal of the large objects common to wastewater streams. Grit removal is also a problem, with the accumulation of grit causing a lack of detention time in the septic tanks. The unavoidable suspended solids from the septic tank along with the inability of the media to slough off solids (as a trickling filter does) has been found to plug the media and forces the wastewater to the surface anyway.

These beds are planted with bulrushes and cattails which, in addition to removing nutrients, are also supposed to provide oxygen to the subsurface area of the media preventing septic conditions and the associated odors.

In actual practice these systems have problems starting with the high oxygen demand placed on the bed by allowing the water to turn septic in the septic tank. The high oxygen demand, in addition to the suspended solids leaving the septic tanks, force high oxygen demand water to the surface where odors have been found to develop. In a study done by W. Daniel Boivin, Evaluation of Constructed Wetlands Performance in New Mexico Mr. Boivin states subsurface flow constructed wetlands are incapable of removing the nitrogen in septic tank effluent to the New Mexico Water Quality Commission standards." Key to this is the need for additional oxygen to assist in the nitrification process.

One of the big selling points in the constructed wetlands systems is the lack of maintenance needed in the system. In actual operation this has not been the case. Maintenance is essential for these systems to operate at the minimal levels obtained in the field. The annual removal of the vegetative growth is needed to keep the systems healthy. This vegetative growth is the SLUDGE removed from the system. In addition, most of the systems have required mechanical aeration, which come with associated electrical and maintenance costs.

Overland Flow Wetlands

Constructed wetlands using surface flows are another type of constructed wetlands found in New Mexico. The surface application of wastewater prevents the plugging of the media noted in subsurface flows. In addition the environment more closely simulates the natural wetland environment found in nature. In this style of wetland treatment it is common for lagoon type systems to be incorporated into the design. The addition of a lagoon provides additional oxygen to the wastewater and provide for treatment through the conventional algae/wind action of the lagoons.

While this design addresses some of the problems with a subsurface flow the problem of odors remain. It stands to reason that a constructed swamp would produce the same type of swamp gasses that are produced in natural wetlands. In addition the wetlands design most often seen does not provide for the BOD loading of wastewater coming from a septic tank. In the overland flow design care must be taken to remove accumulated debris from the system. The addition of Gambusia (a mosquito eating fish) for mosquito control may also be warranted.

Effective Uses of Constructed Wetlands

The most successful wetland operation has been at the end of conventional treatment processes such as Activated Sludge, or Lagoons. In this manner the wetland operates as a polishing process. The filtering action provided by the media and plant growth has been shown to be a viable

option for the filtering of TSS and nonsoulable BOD in treated wastewater effluents. The problem with this is the filtering will also lead to clogging of the wetlands. Treatment for removal of nitrogen has not been as successful. Most data reported on wetlands has been sporadic and inconsistent. Long term testing of wetland effluents, by Michael Richard, Ph. D. on systems in Colorado, shows periodic purging of nitrogen and phosphorus by the wetland systems.

Wetlands Operations and Maintenance

While there is very little an operator can do to control or improve the operation of wetlands, there is maintenance required.

Much of the maintenance is similar to the maintenance of lagoon systems. The dikes need to be maintained. A low growing grass should be planted to prevent erosion. The grass should be cut regularly and the clippings disposed of. Burrowing animals will be attracted to the lush vegetation and need to be discouraged from burrowing into the ground around the wetlands.

Housekeeping is essential to keeping odors, insects and rodents under control. Screenings and grit removed in the pretreatment of the wastewater need to be removed daily and disposed of properly. Trash must not be allowed to accumulate on the grounds and an overall neat and clean appearance should be maintained.

The vegetation growing in the wetland will need to be removed at the end of the growing season. While burning these plants is an option, care needs to be taken to protect the lining of the wetlands as well as any exposed plastic pipe (sampling ports, distribution pipes) in the area. The exposed pipe can be covered with wet burlap and then enclosed by a 5 gallon bucket prior to setting the wetlands on fire. Permits for burning the wetlands also need to be obtained from the proper authorities. Insure that a good supply of water and manpower is available to prevent the fire from escaping the wetland area. The plants can also be cut and the cuttings will need to be removed and properly disposed of.

Process Control Testing

The wetland system needs to be tested. Testing should include pH, temperature, DO, and nitrate. Effluent DO, pH, and temperature testing should be done at least twice a week. Based on this testing, changes to the flow pattern should be made to maintain a minimum effluent DO of 0.5 mg/l. Nitrogen sampling should include both influent and effluent for total nitrogen as well as testing the effluent for nitrate nitrogen. Weekly or at least monthly testing for nitrogen should be considered. In order for this data to be of use, good flow measurements along with a totalized flow will be necessary. The flow measurements need to be taken at the influent and effluent of the facility.

Records need to be kept. The records of flow and process control testing are necessary for the proper operation and maintenance of the system. In addition the operator needs a copy of the as-built drawings and all permit testing done on the facility. Daily records of the temperature and weather conditions will also be helpful in troubleshooting the system.

Phosphorus Removal

Phosphorus as a Nutrient

Phosphorus provides a nutrient or food source for algae. Phosphorus combined with inorganic nitrogen poses serious pollution threats to receiving waters because of high algae growths which result from the presence of the two nutrients in water. Algae in water are considered unsightly and can cause tastes and odors in drinking water supplies. Dead and decaying algae can cause serious oxygen depletion problems in receiving streams which in turn can kill fish and other aquatic wildlife.

By removing phosphorus in the effluent of a wastewater treatment plant, the lake or river that the treatment plant discharges into will have one less nutrient that is essential for algae growth. This reduction in an essential nutrient reduces the growth of the algae.

Need for Phosphorus Removal

The U.S. Environmental Protection agency and other water quality regulating agencies recognize the need to protect rivers and lakes from excessive growths of algae. Because of this, the agencies are requiring that wastewater treatment plants remove phosphorus in the effluent in order to protect the river or stream by eliminating a nutrient that can cause algae growth.

Types of Phosphorus Removal Systems

Lime precipitation, luxury uptake, and filtration following aluminum sulfate flocculation are the most common types of phosphorus removal systems.

Lime Precipitation

When lime (calcium hydroxide ($Ca(OH)_2$) is mixed with effluent from a wastewater treatment plant in sufficient concentration to bring about high pH in the water, a chemical compound is formed which consists of phosphorus, calcium and the hydroxyl (OH^-) ion. This compound can be flocculated or combined in such a way as to form heavier solids which can settle in a clarifier for phosphorus removal. A substantial amount of the lime

reacts with the alkalinity of the wastewater to form a calcium carbonate precipitate which also settles out with the phosphorus sludge.

How the Lime Precipitation Process Removes Phosphorus

There are three general physical or chemical reactions which take place during lime precipitation for phosphorus removal.

1. Coagulation. When chemicals are added to wastewater, the result may be a reduction in the electromagnetic forces which tend to keep suspended particles apart. After chemical addition, the electrical charge on the particles is altered so that the suspended particles containing phosphorous, tend to come together rather than remain apart.
2. Flocculation. Flocculation occurs after coagulation and consists of the collection or agglomeration of the suspended material into larger particles. Gravity causes these larger particles to settle.
3. Sedimentation. As discussed in previous chapters on primary and secondary clarification methods, sedimentation is simply the settling of heavy suspended solid material in the wastewater due to gravity. The suspended solids which settle to the bottom of clarifiers can then be removed by pumping and other collection mechanisms.

Equipment Necessary for Lime Precipitation

Lime precipitation for phosphorus removal requires lime feeding systems, mixing and flocculation areas, chemical clarifiers for sedimentation and the proper pumps and piping for removal of lime phosphorus sludge. Other equipment includes facilities for pH adjustment of the effluent, recovery of the lime, and disposal of the phosphorus sludge.

For a more complete understanding of Lime Precipitation read the section on Phosphorus removal in the Operation of Wastewater Treatment Plants, Volume III, 2nd ed.

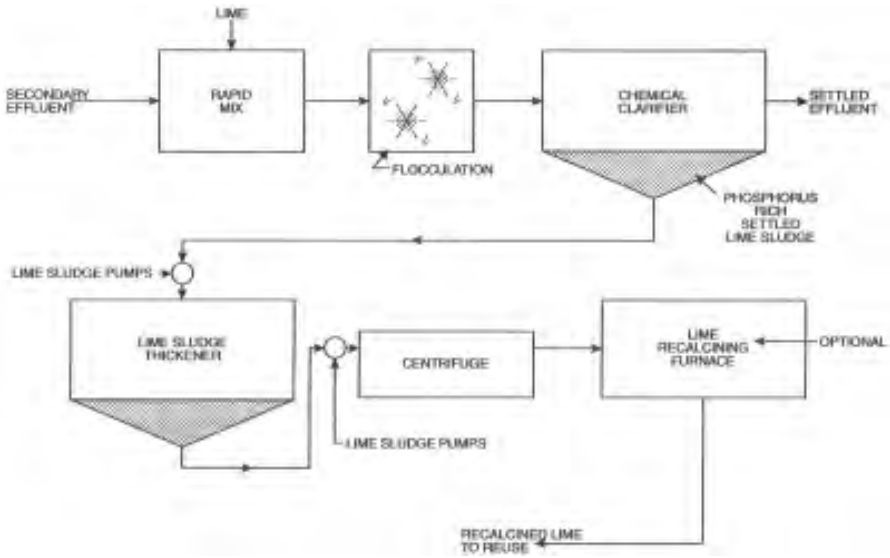

Figure 12.1 - *Lime Precipitation Process*

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LUXURY UPTAKE

Luxury uptake of phosphorus is a biological treatment process whereby the bacteria usually found in the activated sludge treatment portion of the secondary wastewater treatment plant are withdrawn to an environment without oxygen (anaerobic). When the bacteria are faced with the situation of apparent death, the bacteria release phosphorus from their cell structure in large quantities. Phosphorus can then be removed and disposed of by using lime for settling similar to the previously discussed lime clarification

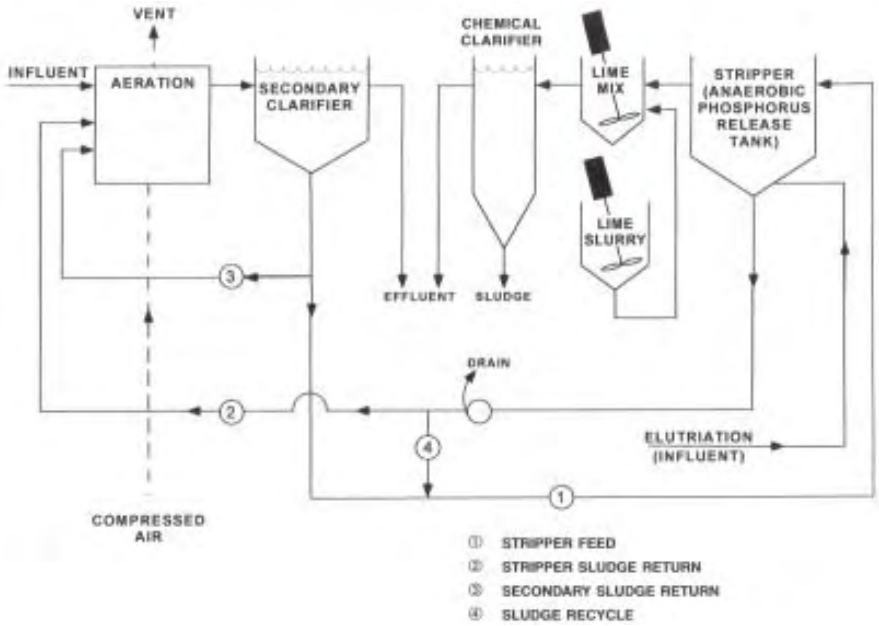

Figure 12.2 - *Luxury Uptake of Phosphorus (elevation flow diagram)*

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process. After the bacteria have released their phosphorus, they are placed back into an ideal environment with oxygen and food. In this environment, since the bacteria are lacking in phosphorus in their cell structure, the first thing they take in is phosphorus. This phosphorus take-up is known as luxury uptake and is used in the process for biological removal of the phosphorus within the wastewater treatment facilities.

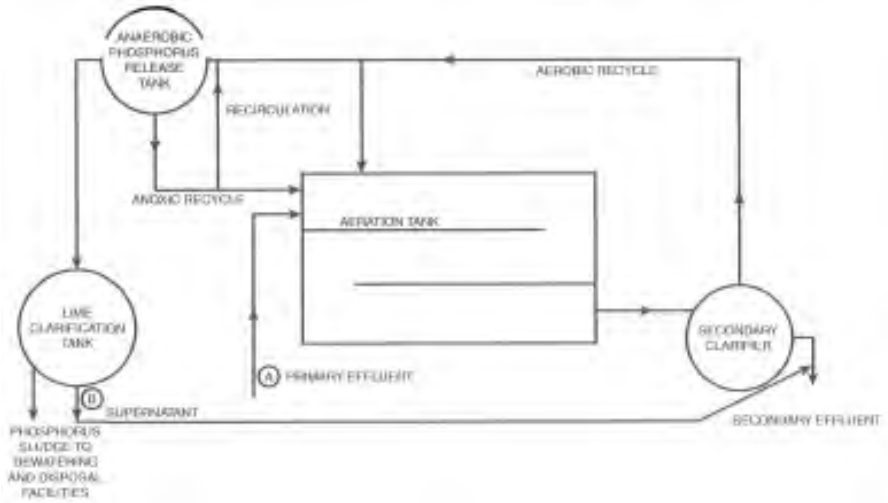

Figure 12.3 - *Luxury Uptake of Phosphorus (plan flow diagram)*

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Bacteria found in normal activated sludge process use phosphorus within the make-up of the cell structure that forms the bacteria. When the bacteria are in a state of Endogenous respiration or are very hungry and need food and oxygen they tend to absorb phosphorus quite freely. This process is called luxury uptake in which the bacteria take excess phosphorus into their bodies due to the stimulation of being placed in a proper environment containing food and oxygen. When these same bacteria are placed in an environment where there is no oxygen (anaerobic), the first element that is released by the bacteria as they begin to die is phosphorus. As the phosphorus is released, it can be drawn off and removed from the wastewater stream.

Wastewater Treatment Units Used

Luxury uptake of phosphorus is found at activated sludge treatment plants. The units used include the standard ones for an activated sludge plant plus a relatively deep detention basin where anaerobic conditions exists.

Another unit commonly found in the luxury uptake and removal system is a lime clarification tank (clarifier) which is usually capable of treating 10 percent of the wastewater flow stream through the treatment facility. Return pumps and piping continue to move the activated sludge through an anaerobic state to a phosphorus release point and back to aeration for the luxury uptake process to begin all over.

Basic Principles of Operation

Because luxury uptake can only take place in a very controlled environment, the bacteria cannot be exposed to any condition which would prevent them from either taking up phosphorus into their cell structure or releasing the phosphorus at the proper time. The basic operation requires the operators to remove the activated sludge from the secondary clarifier and provide the proper detention time in an anaerobic tank for the release to the phosphorus trapped within the cell structure of the bacteria. The operator must closely regulate the time of the anaerobic condition. The bacteria should not be allowed to die. However, the length of time should be sufficient to remove as much of the phosphorus as possible. Return the activated sludge to an area of the aeration tank where sufficient oxygen and primary effluent exist so that the bacteria can be revived and can take up the maximum amount of phosphorus within their cell structure.

ALUMINUM SULFATE FLOCCULATION AND PRECIPITATION (SEDIMENTATION)

Aluminum sulfate (alum) in combination with wastewater also can flocculate phosphorus in much the same way as lime precipitation. The flocculation that happens with aluminum sulfate addition is the formation of aluminum phosphate particles that attach themselves to one another and become heavy and settle to the bottom of a clarifier. The aluminum sulfate and phosphorus mixture can then be withdrawn, thereby removing the phosphate or phosphorus from the wastewater flow. This alum floc is difficult to settle out in a clarifier. Therefore, a sand or mixed-media filter is usually placed after the clarifier to remove the remaining floc.

Aluminum sulfate (alum) can be used in the same manner as lime for precipitation of phosphorus in a clarifier. The same principles of coagulation, flocculation and sedimentation apply when using alum for the removal of phosphorus in effluent from a secondary treatment facility. However, because of the difference in cost between aluminum sulfate and lime, lime is more commonly used for the precipitation of phosphorus.

When alum is used for phosphorus removal, two general reactions occur. In the first reaction, alum reacts with the

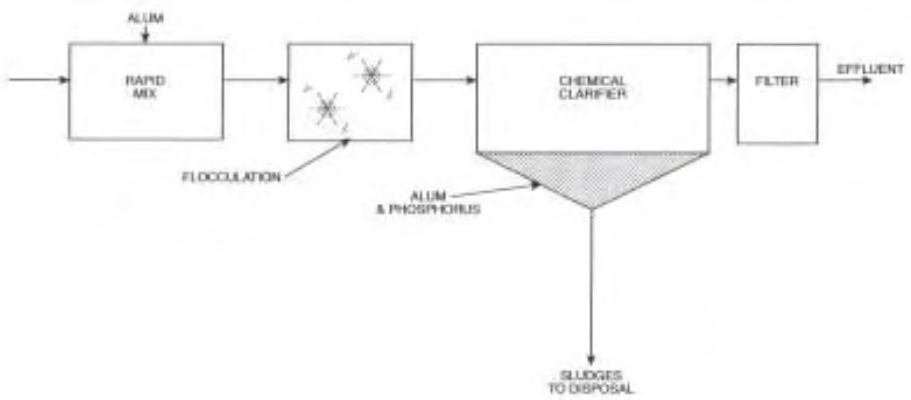

Figure 12.4 - *Alum Flocculation as used in a Clarification Process*

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alkalinity of the wastewater to form an aluminum hydroxide floc.

Phosphorus removal is by the formation of an insoluble complex precipitate and by adsorption on the aluminum hydroxide floc. Depending on the alkalinity of the wastewater, dosages of 200 to 400 mg/l of alum are commonly required to reduce phosphorus in the effluent down to 0 to 0.5 mg/l. Optimum phosphorus removal is usually achieved around a pH of 6.0. Alum feed is frequently controlled by automatic pH equipment which doses according to the pH set point (the more alum, the lower the pH). Jar tests can be used to determine the optimum pH set point and alum dosage rate.

If it is necessary to achieve low effluent phosphorus residuals (less than 1.0 mg/l) in the effluent, the chemical clarifier is usually followed by either a pressure filter or a multi-media gravity filter. Phosphorus sludge from the clarifier goes to dewatering and disposal facilities. At present, there are no economical methods available for alum recovery.

References

Office of Water Programs, California State University, Sacramento, *Operation of Wastewater Treatment Plants*, Volume III, 2nd ed.,