ABC ENVIRONMENTAL LLC

PHOSPHORUS CONTROL
ABC 601

Phosphorus is an essential nutrient needed in the cells of all living things. Phosphorus is used in the production of nucleotides, phospholipids, and nucleic acids and for energy transfer. Energy is produced in a cell when Adenosine triphosphate (ATP) releases a phosphate group and becomes Adenosine diphosphate (ADP). ATP and ADP have become known as the energy currency of the cell. Phosphorus can be found in animal and plant cells (organic phosphorus) and can be produced in inorganic forms of phosphate from decomposition. Phosphorus in the natural environment cycles around in a process known as the phosphorus cycle. However, an abundance of phosphorus in an ecosystem becomes pollution.

When an aquatic ecosystem becomes nutrient polluted or enriched it is classified as eutrophic. Cultural eutrophication is when people are responsible for the accelerated aging of the lake or stream. “Scientists estimate that roughly eighty (80%) percent of nitrogen and seventy-five (75%) percent of phosphorus entering lakes and streams in the United States comes from human activity.” (Owen & Chiras, 155) Also, roughly eighty-five (85%) percent large lakes are undergoing eutrophication.

A major problem associated with phosphorus rich waters are algal blooms or “pea soup” conditions. Algae need phosphorus for growth and will multiply quickly when a lot of phosphorus is available. Phosphorus is introduced to the water shed by means of wastewater from detergents, decaying fecal matter and from industry. Detergents are high in phosphorus. “Most dishwater detergents are about forty-five (45%) percent phosphate—just to prevent those ugly spots.” (Andrews & McEwan, 103) Large amounts of point source (direct discharge) phosphorus pollution comes from waste water treatment plants, with most treatment plants only removing about one third of the phosphorus. Phosphorus is found in wastewater as orthophosphate, polyphosphate and organic phosphate. Non-point source (indirect discharge) accumulates from decaying wastes on farm feed lots and fertilizer runoff from farms and lawns.

The effects of algal blooms are many:

1. It destroys the aesthetics of the lake, rendering it repulsive to swimmers and other sports enthusiasts. Canoe paddles, motor boat propellers, water skis and fish lines, become fouled up in the green slime.
2. The bloom impairs water quality by giving it a bad taste and odor. If a lake is source of drinking water, considerable expense may be involved in improving its quality.
3. As a result of wind and wave action, huge masses of algae (and even rooted plants that may have torn losses from the lake bottom) can pile up along the shore and decompose. Hydrogen sulfide (H_2S) gas is given off. This gas smells like rotten eggs eggs and in high enough concentrations it is also toxic.
4. Some of the blue-green algae releases chemicals that are poisonous to fish and humans. (Owen & Chiras, 155)

Balance must be restored. People have begun taking steps to prevent cultural eutrophication. Most states limit phosphorus concentrations in laundry soaps and fertilizers are being more closely monitored for phosphorus levels. Some wastewater treatment plants have started regulating phosphorus in the effluent releases. In the wastewater treatment field there is tremendous potential to control the amount of phosphorus being discharged into the environment.

CHEMICAL PRECIPITATION

Chemical precipitation and biological process are the two main techniques used to remove phosphorus from wastewater. Chemical precipitation of phosphorus is the more common method at present, but certainly is not ideal. This technique removes phosphorus in wastewater with the addition of chemicals, most commonly, metal salts such as ferric chloride, ferric sulfate (pickle liquor), aluminum sulfate (alum) or lime (calcium oxide). Lime was once the most common precipitant used for phosphorus removal. However, in recent years its usage has tapered to a minimum. Substantial increases in sludge production, storage, handling and feeding of lime are all factors that have caused a decrease of its use in phosphorus removal. Alum and ferric chloride have become the most used coagulants. "Coagulation neutralizes the electrical charge which cause particles to repel each other. This allows the particles to cling together to form large flocs." (Cortinovis, 44) The large flocs will settle out and can be removed as sludge.

The reaction with alum and phosphorus is as follows:

$$Al_2 (SO_4)_3 + 14H_2O + 2PO_4^{3-} = 2AlPO_4 + 14H_2O + 3SO_4$$

The atom is such a small particle, which is virtually impossible to track a single atom. The term mole, derived from the Latin word meaning "heap" or "pile", is used to describe a collection of atoms, ions or molecules. One mole of Aluminum (Al) will react with one mole of phosphorus (P) or phosphate (PO_4). However, the ratio of one mole of commercial alum to one mole of P is 9.7 to 1. Furthermore, coagulation studies show that this dosage is not sufficient in removing the phosphorus from the wastewater because of competing reactions that vary with wastewater influents. Factors such as pH, fluorides, sulfates, and sodium effects removal. To satisfy removal rates of seventy-five (75%) percent, eighty-five (85%) and ninety-five (95%) percent or greater, ratios of 13:1, 16:1 and 22:1 are needed.

The iron compounds commonly used for phosphorus removal are ferric chloride, ferrous chloride, ferric sulfate, and ferrous sulfate. Ferric (Fe^{2+}) and ferrous (Fe^{3+}) are iron ions (charged atoms) and must be used according to the appropriate pH levels for the waste stream being treated. The reaction between ferric chloride (most commonly used) and phosphate is:

FeCl3 + PO43- = FePO4 + 3Cl

The mole ratio of Fe to P is 1:1. The weight ratio of the ferric ion phosphorus 3.2:1. Approximately 150 mg/l of commercial ferric chloride will treat wastewater with 10mg/l of phosphorus.

The primary concern of chemical additives for nutrient removal is increased sludge production. In most cases, sludge production will increase thirty (30%) percent to sixty (60%) percent with use of chemical precipitants. Chemical additions for phosphorus removal mean a treatment facility will not only pay for the chemical purchase, but will also have to pay for its removal. In our world, land is a limited commodity, so it does not make sense to create more sludge and take up precious space. Many facilities send their sludge to be incinerated. We have cleaned the water but now polluted the air. With greenhouse gases exceeding the natural limits, incineration falls short of a true solution. Sludge or bio-solids are already difficult for treatment plants to dispose of, why create more.

Chemical additions cause side effects that should be mentioned. “Alum causes the release of carbon dioxide, which forms carbonic acid” (Cortinovis, 46) Carbonic acid lowers pH in the wastewater. Other effects from chemical usage are the varying properties and safety requirements ranging from corrosion, irritating mucous membranes and being caustic. The end user must be concerned for their safety since these chemicals are not user friendly. “some of the iron coagulants have left unsightly red stains throughout various treatment plants” (EPA 11010FLQ03/71, 56) Chemical precipitation of phosphorus is a useful tool but leaves much room for technique improvement.

BIOLOGICAL PROCESS

Single cell prokaryotes or bacteria are the first forms of life and fossils indicate that they were on earth 3,500,000,000 years ago. The only life forms found in the most extreme environments on earth are bacteria. Microorganisms are being utilized in different industrial and commercial applications but only to a fraction of how bacteria are utilized in nature. Man makes yogurt and antibiotics with the help of microbes, but everything in the natural world is dependent on bacteria. They are the base of the food chain and can kill the most ferocious beast in the forest. Why would anyone not tap the potential of this natural wonder for a phosphorus removal technique in wastewater treatment?

It is only in the last five to ten years that most wastewater treatment operators have come to realize “it’s not the pumps, it’s the bugs!” Microbes are used in wastewater treatment commonly. However, it is rare to find facilities that have biological nutrient removal (BNR) in place. The less recalcitrant carbonaceous wastes are removed from the wastewater with the help of heterotrophic bacteria. If air is pumped into a swimming pool, tank or pond that is filled with municipal domestic sludge, you have created a simple activated sludge plant to remove carbonaceous waste. Many operators know why this works, but the key to the future is to be involved with how it works.

Wastewater treatment has progressed as a science and biological nutrient removal is becoming more common. Many plants undergo the nitrification process in which they grow certain strains of microbes to convert ammonia into ammonia into nitrate. Then to remove the nutrient, other strains of bacteria convert the nitrate into nitrogen gas and release it into the atmosphere (which is approximately seventy-eight (78%) percent nitrogen. The wastewater field has moved away from treating ammonia with chemical additions and biological nitrogen removal is the method of choice. However, biological phosphorus removal is not as common, yet. It seems that the lack of understanding of the process, has accelerated chemical removal of phosphorus. Just as computers, cars and telephones were once rare and have evolved into common objects that people have become dependent upon, so it will be with the use of biological phosphorus removal from wastewater. Studies over the last fifty years have already lead to some exciting breakthroughs in phosphorus removal.

“Conventional secondary biological treatment systems accomplish phosphorus removal by using phosphorus for biomass synthesis during BOD removal” (EPA/625/1-87/001, 15)

Microorganisms need phosphorus in the wastewater but typically use only ten (10%) percent to thirty (30%) percent of what's available. There are methods to influence the bacteria to take up more phosphorus then needed. Experiments done in the late fifties showed that vigorous aeration of mixed liquor caused high rates of phosphorus removal. The term "luxury uptake" is used to describe the process performed by the bacteria. Still not much was known about the how's and why's. Further experimentation throughout the sixties and seventies lead to several specialized treatment plants. The Phosphstrip, Modified Bardenpho (or Phoredox), A/O Process, UCT and Modified UCT systems were all experimented with. Each of these techniques was designed to cultivate the right blend of microbes to produce maximum phosphorus removal. They implemented different combinations of aerobic, anaerobic, anoxic zones and/or light chemical additions of return streams in activated sludge plants.

All the different styles of treatment have an important common denominator, biological removal of phosphorus. The aerators, return pumps, plug flow basins, anoxic zones and reactor clarifiers would be useless without bacteria they helped to grow. Test results from these various techniques showed similar strains of bacteria were present from treatment plant to treatment plant when there was a high rate of phosphorus removal. Pseudomonas, Acintobacter, Aeromonas and Bacillus genus were identified " These microbes are capable of 'luxury uptake', or the dead storage of phosphorus, typically as polyphosphates granules (EPA 430/G-73-008, 164) "These poly phosphates are part of a volutin granules that also contain lipids, proteins, RNA and magnesium" (EPA/625/1-87/001.18)

A major design feature in specialized treatment plants for phosphorus removal is creating anaerobic zones. These anaerobic stages make it possible to cultivate the strains necessary for phosphorus removal. Fermentation, or the breakdown of carbohydrate products, yields polyhydroxybutrate (PHB). The PHB is preferred by the slow growing phosphorus-storing bacteria enabling them to grow quicker and more abundantly. "Thus, the anaerobic phases result in a population selection and development of phosphorus-storing microorganisms." (EPA/625/1-87/001,18) In other words, an anaerobic zone prior to the aerobic zone grows the needed bugs for phosphorus removal. When these bugs go into the aerobic stages with high oxygen levels available they will uptake massive amounts of phosphorus. Without the anaerobic zones, the right bugs might not be present.

At present, developments have made biological phosphorus removal possible to many existing treatment plants without BNR design capabilities. Bioaugmentation, adding selected strains of bacteria to treatment plants is the method. Bioaugmentation addition is an easy and economical way to remove phosphorus, therefore saving on time, costly capital improvements, violations of environment regulations and the use of chemical to further pollution. BEC 601 is potent combination of billions of microbes designed for phosphorus removal. BEC 601 is non-toxic, non-corrosive, biodegradable and it works! With the use of BEC 601, operators can add the proper strains of bacteria to achieve phosphorus removal and receive the benefits of biological nutrient removal, with less costly sludge disposal bills. They also minimized the use of harmful chemicals. Best of all, there is a high quality effluent with a job wisely done.