Removing nitrogen and phosphorous

Nitrogen

Nitrogen removal is done through aerobic and anoxic processes.

Aerobic zone

Nitrification is an aerobic process, which involves converting ammonium in wastewater into nitrates. Two types of bacteria are responsible for nitrification, Nitrosomonas and Nitrobacter. The Nitrosomonas oxidise ammonia (largely from urine) to the intermediate product nitrate (NO_2). The Nitrobacter convert nitrate to nitrite (NO_3). The conversion of ammonia to nitrite involves a complex series of reactions. Significant oxygen is required for the conversion. Aeration supplies the oxygen needed by the bacteria to drive the reaction.

Approximate equations for the reactions can be written as:

For Nitrosomonas:

$$2NH_4 + 3O_2 \rightarrow 2NO_2^- + 2H_2O + 4H + \text{new cells}$$

For Nitrobacter:

$$2NO_2^- + O_2 \rightarrow 2NO_3^- + \text{new cells}$$

Anoxic zone

The next step in the process is removing nitrate and forming nitrogen gas (or denitrification). An anoxic environment is critical to enable denitrification.

Under anoxic conditions, there is no 'free' oxygen in the water. Facultative bacteria use either 'free' oxygen, or the oxygen in nitrate for their metabolic processes. When there is no 'free' oxygen, they use the oxygen from nitrate for their metabolic processes, resulting in the release of nitrogen gas.

Several types of bacteria are responsible for converting nitrate to nitrogen gas (N_2). The basic path for reducing nitrate to nitrogen gas is:

NO_3^-	→	NO_2^-	→	NO	→	N_2O	→	N_2
nitrite		nitrate		nitric oxide		nitrous oxide		nitrogen gas

Phosphorus

Removal of phosphate by phosphate accumulating organisms (POAs) is a two-step process. POAs initially release phosphorus to the mixed liquor under anaerobic conditions, and later on in an aerobic phase of treatment, take up much larger quantities of phosphorus. We can then remove this phosphorus as part of excess sludge.

Anerobic zone

In the anaerobic zone, volatile fatty acids (VFAs) are introduced as additional food for the POAs. When there is no oxygen available, the POAs take up the VFAs and release phosphate to the mixed liquor.

The POAs now have a large supply of energy in the form of stored volatile fatty acids for metabolism and growth.

Aerobic zone

In the aerobic zone, there is a large increase in the mass of POAs, which are now capable of absorbing much more phosphorus from the mixed liquor than they released during the anaerobic stage. The phosphate Is now part of the bacterial cell mass and is removed as sludge in the clarifier.

Removing phosphorous is important as it contributes to eutrophication, where nutrient-rich water leads to an overgrowth of weeds, algae and cyanobacteria (blue-green algae), causing algal blooms, depleting oxygen and killing animal life.

Removing phosphorous is also important to improving efficiency at water recycling plants, as high phosphorous levels can effect water recycling equipment such as reverse osmosis membranes.