Phosphorous in Wastewater

- The major sources of phosphorus in raw wastewater are derived from human, domestic and industrial wastes, atmospheric deposition and run-off from phosphorus-rich fertilized land.
- Often a high proportion of phosphorus originates from detergents and cleaning compounds. Phosphorus occurs in natural waters and wastewaters almost solely as phosphates.
- These phosphates include organic phosphate, particulate polyphosphate and inorganic orthophosphate.

Phosphorus Removal

- The general purpose of phosphorus removal is to eliminate the excess phosphorus content from wastewater discharged to receiving waters and then to utilize this excluded phosphorus load in the way which is the most proper for the natural phosphorus cycle in nature.
- Phosphorus can be chemically or biologically removed:

Chemical treatment involves direct precipitation for the physical removal of P compounds while the biological removal involves bacteria removing phosphorus via their metabolic pathways.

I. Chemical phosphorus removal

The chemical treatment for phosphorus removal involves the addition of *lime or metal salts* to react with soluble phosphate to form solid precipitates that are removed by solids separation processes including clarification and filtration.

1. Direct precipitation
2. Pre-precipitation
3. Co-precipitation
4. Post - precipitation

1. Direct Precipitation:

The chemicals most often employed are compounds of calcium, aluminium, and iron.

Calcium: Lime is the most common calcium salt used for phosphorus precipitation.

$$CaO + H_2O \rightarrow Ca(OH)_2$$

$$Ca(OH)_2 \rightarrow Ca^{2+} + 2OH^-$$

$$10Ca^{2+} + 6PO_4^{3-} + 2OH^- \leftrightarrow Ca_{10}(PO_4)_6(OH)_2$$

This precipitation usually occurs within the pH range of 8 to 11.

Aluminium: The major chemical used for precipitation is aluminium sulphate (alum), which undergoes the following reaction:

$$Al_2(SO_4)_3.14H_20 + 2PO_4^{3-} \rightarrow 2AlPO_4 + 3SO_4^{2-} + 14H_20$$

For effective removal of P from the waste water the alkalinity must be high enough to buffer the aluminium sulphate; with acidic wastewaters, the alkalinity has to be adjusted.

Iron(III): Ferric ions are mainly responsible for phosphorus removal and the salt most commonly used in wastewater treatment is ferric chloride. Iron(II) ions can be used only if they are first oxidised to the iron(III) form that form strong complexes with pyrophosphate and tripolyphosphates, which are then probably removed by adsorption onto iron(III) hydroxo-phosphate surfaces.

2. Pre-precipitation:

- This process includes the treatment of raw/primary wastewater and falls in the general category of chemical precipitation processes.
- Phosphorous is removed with 90% efficiency.
- The chemical dosage for P removal is the same as the dosage needed for organic matter (BOD) and suspended solids removal, which uses the main part of these chemicals.

3. Co-precipitation:

- The co-precipitation process is particularly suitable for active sludge plants, where the chemicals are fed directly in the aeration tank or before it. The continuous sludge recirculation, together with the coagulation-flocculation and adsorption process due to active sludge, allows a reduction in chemical consumption of the coagulant used for removal of P.

4. Post-precipitation:

- The post-precipitation is a standard treatment of a secondary effluent, usually involving the metallic reagents for removal of P.
- It is the process that gives the highest efficiency in phosphorous removal. Efficiency can reach 95%.
- The disadvantages of the process are high costs for the treatment plant (big ponds and mixing devices are needed) and sometimes a too dilute effluent.
- In case ferric salts are used in the post precipitation process, there is also the risk of having some iron in the effluent, with residual coloration.

II. Biological process removal

- The principal advantages of biological phosphorous removal are reduced chemical costs and less sludge production as compared to chemical precipitation.

- The commonly employed biological processes for P removal include:

1. Assimilation
2. Enhanced biological phosphorus removal (EBPR)

1. Assimilation:

- Phosphorus removal from wastewater has long been achieved through biological assimilation – incorporation of the P as an essential element in biomass, particularly through growth of photosynthetic organisms.

2. Enhanced biological phosphorus removal (EBPR):

The basic theory for enhanced biological phosphorus removal relies on selecting P accumulating organisms (PAO) capable of storing more phosphorus than other bacteria naturally found in activated sludge through alternating anaerobic and aerobic zones.