

WHITE PAPER



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Nutrient Removal (P-Removal) at Wastewater Treatment Plant

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WHY IS PHOSPHORUS IN OUR WASTEWATER EFFLUENT AN ISSUE?

Nutrient pollution is the primary cause of eutrophication of surface waters where excess nutrients, generally nitrogen and/or phosphorus, stimulate algal growth. The regulatory mechanism, a Total Maximum Daily Load (TMDL), prescribes the maximum amount of a pollutant (i.e. phosphorus in this instance) that a body of water can receive while still meeting the U.S. Clean Water Act water quality standard. One (1) pound of phosphorus can produce up to 111 pounds of algae biomass.

What is prompting action now?



Phosphorus limitations on wastewater treatment facility effluent is an Environmental Protection Agency (EPA) requirement. In 2012, the Indiana Department of Environmental Management (IDEM) held stakeholder meetings to discuss Indiana's approach in meeting this requirement. In 2013, IDEM held internal meetings to further discuss application and implementation of a phosphorus limit.

At a recent American Council of Engineering Companies (ACEC) Environmental Business Committee meeting, IDEM has indicated that "official" notification from the Office of Water Quality (OWQ) for all major dischargers (those that are permitted to discharge a daily average flow of 1.0 Million Gallons per Day or more) will receive a monthly average Phosphorus limitation of 1.0 mg/l upon the next permit renewal. Statewide adoption is merely around the corner!

What options are there for achieving required Phosphorus Removal (P-Removal)?

WWTP effluent of ≤ 1 mg/l phosphorus can be achieved through the application of chemical, physical, and/or biological means. For the noted effluent limitation, it is most common to compare the alternatives

for, and associated pros and cons of, chemical versus biological P-removal before determining the desired resolution route.

Chemical P-Removal has the following general advantages and disadvantages worth considering:

- ⇒ **Advantages:** No modification to biological process; Optional points of application; Rapid reliable reaction; Low resulting effluent total phosphorus; Not affected by biology / toxicity; Improvements in activated sludge settleability; Operation insensitive to changes
- ⇒ **Disadvantages:** Cost of chemicals; Increased waste sludge production; Increased inorganic waste sludge content; Increased mixing requirements (due to heavier mixed liquor); reduction in clarifier solids loading capacity

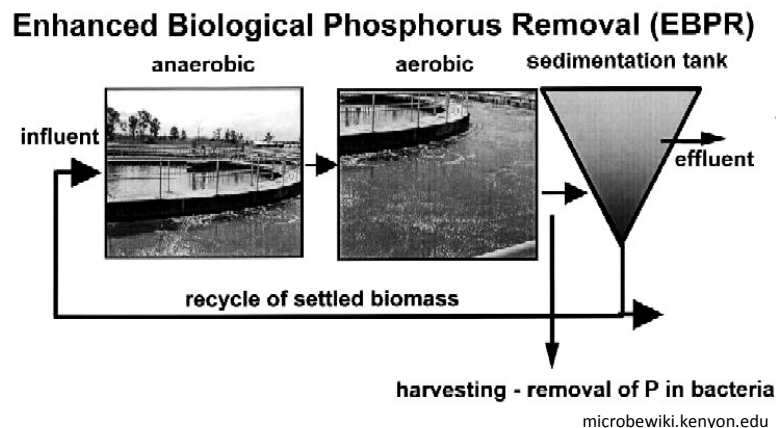
Enhanced Biological Phosphorus Removal (EBPR) has the following general advantages and disadvantages worth considering:

- ⇒ **Advantages:** Elimination of chemical costs; Effluent P concentrations <0.2 are possible; No increase in waste sludge production; provides control of filamentous growth; Improves activated sludge settleability; Reduces O_2 transfer requirements for BOD removal / improves oxygen transfer rate; Improves nitrification rate.
- ⇒ **Disadvantages:** Requires modification of biological process (i.e. anaerobic – aerobic sequencing); Effluent P concentrations are determined by volatile fatty acid (VFAs) to total Phosphorus ratio in the influent to anaerobic zone (i.e. care should be taken to determine if supplemental VFAs are required before selecting this alternative); Can be affected by biological toxicity. Performance is more sensitive to influent flow and pollution loading variations.

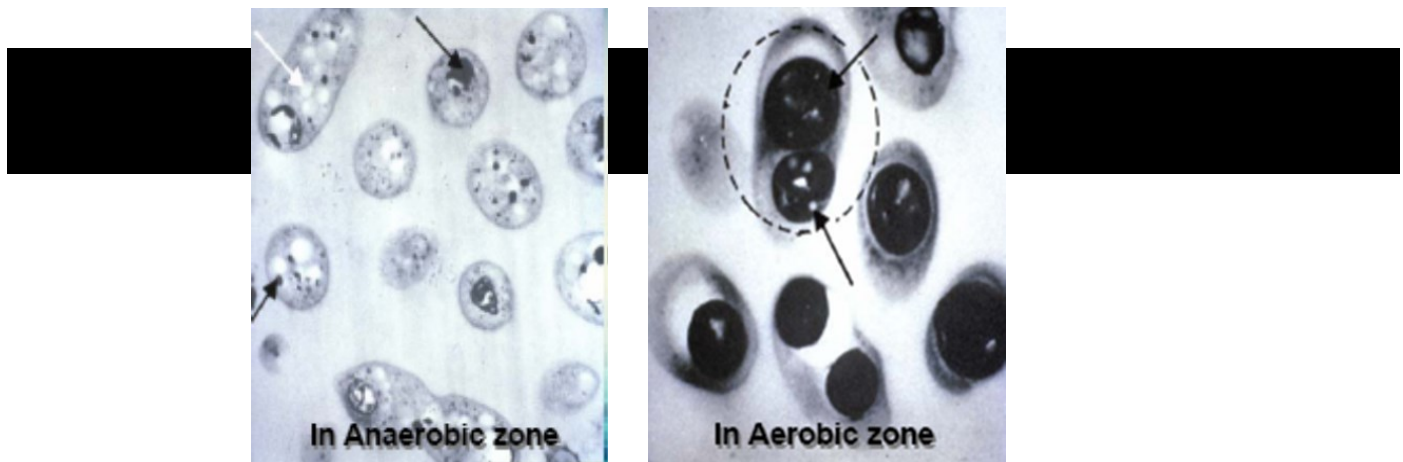
What exactly is Enhanced Biological Phosphorus Removal (EBPR)?

Removal of settleable solids provides some Phosphorus Removal (5-15% in primary sedimentation). Biological WWTPs will typically remove approximately 20 to 40% of influent phosphorus (through primary clarification and the standard activated sludge process). With the identified pending 1 mg/l effluent limitation on Phosphorus, many WWTP facilities can be retrofitted to provide for biological phosphorus removal; we call this EBPR.

EBPR is a process that promotes the accumulation of bacteria called phosphate accumulating organisms (PAOs) that use Phosphorus as an energy storage mechanism. It is typically achieved through cycling the activated sludge biomass between Anaerobic and Aerobic conditions.



- ⇒ **Anaerobic Conditions:** Heterotrophic Bacteria break down organics to volatile fatty acids (VFAs). PAOs out-compete other aerobic heterotrophic bacteria for food when anaerobic. Zones are included in the activated sludge process. PAOs store soluble organics by releasing ortho-P into solution which provides the needed energy to accomplish this.
- ⇒ **Aerobic Conditions:** Rapid aerobic metabolism of stored food occurs. PAOs uptake an excessive amount of phosphorus. Biomass of approximately 5-7% P by weight is generated (this biomass is normally 1.5-2% P by weight in a conventional activated sludge process). More P taken up than released (consumed).



Note: From the above the bioaccumulation of P is evident!

What important factors should be considered when assessing viability of EBPR?

- 1) Is there adequate influent BOD (enough O₂ demand to achieve anaerobic conditions)?
BOD: P ratios typically 20:1 or higher are desired.
- 2) Are we able to alter the process to provide adequate anaerobic detention time?
Typically 30 minutes to 3 hours depending on the existing process under modification.
- 3) Are we able to adequately accommodate the requirements for aerobic detention time?
Typically 4-5 hours for required BOD removal and more for nitrification.
- 4) Are side stream flows accounted for?
Supernatant P can overload P removal systems.
- 5) Have we identified and accommodated any commercial/industrial inhibitory contributors?

What cautionary consideration should be applied when implementing a EBPR improvement?

First, it is currently IDEM's stance that a secondary (backup/trimming) chemical means of treatment be provided. EBPR is sensitive to variations in influent flows and loads. That being said, it is possible to achieve a $\leq 1\text{mg/l}$ P-concentration in the WWTP's effluent through solely implementing EBPR.

Additionally, to successfully achieve Bio-P removal, the following additional considerations are recommended:

- 1) Close control is required (knowing the levels of P in anaerobic and aerobic, and knowing the D.O. in anaerobic and aerobic) – this lends toward more extensive automation and controls.
- 2) An evaluation of existing sludge handling capacity (to ensure that any chemical addition that may be used to supplement the EBPR process alternations do not overwhelm the existing facilities).
- 3) An ability to minimize the existing sludge blanket in final clarifiers (to avoid P release).
- 4) Control of the MLSS concentration to maintain a low to mid-range SRT value.
- 5) An ability to reduce the clarifiers surface overflow rating (SOR) from 1000 (Extended Air) to 900 (P-Removal) if chemical treatment is included.
- 6) Limiting NO_x entering the anaerobic zone in significant amounts (as NO_x inhibits phosphorus release).

Generally speaking, design and operation requirements are more sensitive when incorporating EBPR.

WE CAN HELP!

Commonwealth recommends a 2-Phased Approach a typical P-Removal project at a WWTP; with the first phase consisting of identifying possible alternatives and associated costs (as outlined below).

Phase 1

- ⇒ Initial kick-off meeting to obtain existing sampling data / monthly reports of operation (MROs) and discuss how the plant is currently operated along with the Operators vision and desires for future operations.
- ⇒ Engineer assembles recommended sampling plan to properly characterize the waste streams. Provide sampling plan to the Owner.
 - Owner takes samples at locations and frequencies recommended and performs necessary laboratory analyses.
- ⇒ Owner provides Engineer with waste stream and waste sludge characterization results along with 3 to 5 years of digital MROs.
- ⇒ Engineer develops a basic population projection to determine expected growth in 5, 10, 15, and 20 years future time frame.
- ⇒ Engineer projects wastewater flows and pollutant parameter loads expected in the 5, 10, 15, 20 year future time frames. Pollutant parameters will include total suspended solids, bio-chemical oxygen demand, total Kjeldahl and ammonia nitrogen and phosphorus.
- ⇒ Engineer assembles a technical memoranda assessing alternatives and opinions of probable construction cost and annual operation/maintenance/& replacement costs for biological, chemical, and combination biological and chemical P-removal (along with associated pros and cons).
 - A comparison of alternatives on a cost effective basis will be clearly presented within the technical memoranda.
- ⇒ Engineer makes recommendations within the technical memoranda on the scope of the P-removal project.



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WOULD YOU LIKE MORE INFORMATION?

Please contact Al Stong, P.E., Brady Dryer, or Don Larson for more information:



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