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Phosphorus Removal in Wastewater Treatment

(Final Report)

Research and Development Section
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Executive Summary

The objective of this Study is to review available phosphorus removal processes, both biological and chemical, for secondary sewage treatment works in Hong Kong.

Sewage treatment is to reduce pollutants discharged to the environment, the control of nutrients discharged from municipal sewage treatment works can be important in preventing eutrophication. At present, only nitrogen removal is required in some of the sewage treatment works. If phosphorus (P) removal becomes a requirement, either chemical precipitation or *enhanced biological phosphate removal* (EBPR) would have to be added.

Chemical P removal can be primary-, secondary-, tertiary-precipitation. Multiple-point addition is also possible. Dosing of iron(III) and aluminum(III) metal salt are common. Chemical P removal depends on very rapid chemical reaction and there is no need to modify the biological treatment process. The operator can control the effluent ortho-phosphate (OP) by controlling the chemical dose. It is possible to achieve very low effluent OP concentration (say <0.1mg/L). When compared with chemical P removal, EBPR can greatly reduce chemical costs and to avoid large increase in waste sludge production. Other than the additional cost of chemicals, one major drawback of chemical precipitation is the additional sludge that is produced, and pre-precipitation can produce the highest amount of inorganic sludge.

EBPR is the removal of removal of P exceeding metabolic requirement by bacteria called phosphorus accumulating organism (PAO). In EBPR mechanism, an anaerobic-aerobic cycle reaction is important. The A/O process is the most basic EBPR, but it does not perform nitrogen (N) removal. A2O, UCT and modified-UCT (MUCT) are common biological processes that can handle both N and P removal. Influent volatile fatty acid (*VFA*) favors EBPR, the addition of primary sludge fermentation can boost EBPR. Other factors favoring P removal in EBPR plant included: (i) shorter sludge age, (ii) avoid secondary P release, (iii) remove nitrate from recycled streams, (iv) apply chemicals for P removal only after finishing with biological P removal, (v) maintain some denitrification in final clarifier to avoid P release. The reversible nature of biological phosphate storage can result in high OP in *sludge* liquor and side streams. Care will have to be exercised in design and operation to avoid high P returns.

For an effluent discharge requirement in total phosphorus (TP), it is the sum of cellular P and OP. A moderately high effluent TSS can cause exceedance of discharge license in TP due to biomass which may have 2-8% P dry weight. With final clarifiers, a

stringent control of effluent TSS favors a low effluent TP. Membrane technologies such as MBR can be helpful in this regard.

EBPR and chemical P removal can be applied together. Simultaneous chemical dosing before final clarifier, and Tertiary-precipitation (after final clarifier) before tertiary filter are feasible. In fact, the operator can control the effluent OP by controlling chemical dose.

Retrofitting of an existing biological treatment works to a P removal plant can consider (i) chemical P removal, (ii) EBPR, or (iii) a combination of both. It is relatively easy and inexpensive to install metal salt dosing equipment for chemical P removal. For retrofitting a N-removal plant to N- and P-removal, EBPR processes such as A2O, UCT and modified Bardenpho are possible.

Shek Wu Hui sewage treatment works (SWHSTW) may require to removal P in the future. A future discharge standard of BOD_5 10 mg/L, TSS 10 mg/L, TP 1.0 mg/L, NH_3-N 1.9 mg/L, TN 8.0 mg/L is assumed. The activated sludge process of SWHSTW was simulated using BioWin software. A calibrated model was developed based on 2006 data in a completed R&D study (RD2037). BioWin modeling was performed to compare original process configuration (so-called ‘original MLE’) with different EBPR processes (namely A2O, UCT and MUCT). Effluent OP levels were compared for simplicity. Simulation results showed ‘original MLE’ performed similar to pure-MLE process which focused on N-removal only. All three EBPR processes confirmed that a process modification to A2O, UCT or MUCT can improve effluent OP. (total tankage unchanged and 67% aerobic zone unchanged). After tests with few different combinations of partitioning the anaerobic and anoxic zones in these processes, they were predicted to reduce average effluent OP to 1.0 mg/L or less (from 2.2 mg/L predicted ‘original MLE’). Noted however there was a slight increase of effluent nitrate in A2O, a moderate increase in UCT, and a higher increase in MUCT.

Among the three EBPR processes evaluated by Biowin modeling, A2O process has merits of being a proven technology, favorable construction costs and somehow easier to operate. Given the same sewage flow and characteristics, bioreactor volume, temperature, aerobic fraction, and biokinetic parameters in BioWin, it has been repeatedly found in activated sludge process modeling that biological P-removal always *competes* with N-removal. As an example, a higher mix-liquid return (MLR) flow is a common and acceptable operational option to boost denitrification so to reduce effluent nitrate, thus to reduce total nitrogen. However, this operation would deteriorate effluent OP. For serious EBPR, control of OP released from sludge and recycled streams can be important. Effluent TSS may have to be closely monitored to control effluent TP. If effluent OP is slightly high, boosting of VFA in sewage by primary sludge fermentation can be considered.

There are some biological treatment plants in the world that simply adopted chemical P removal, or a combined EBPR+chemical that relies heavily on chemical dosing. The reuse of P from chemical sludge is difficult. P is a depleting resource globally. The choice of EBPR (without chemical dosing) allows the possibility of P recovery, for example, as struvite, to achieve more sustainable wastewater treatment.