Occurrence and implication of dissolved organic phosphorus (DOP) in tertiary wastewater effluents

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Introduction

The increasingly more stringent phosphorus (P) discharge limits, which are below the concentrations reliably achievable with currently technologies, demand for better understanding of phosphorus removal mechanisms and presented challenges of how to further remove the phosphorus to extremely low levels (e.g. TP<5-10 µg/L) at wastewater treatment plants. A few previous studies (Benisch et al., 2007; Neethling et al., 2007; Lancaster and Madden, 2008; Gu et al., 2009, 2010) evaluated the effluent TP fractions in a number of different advanced tertiary P removal processes and they showed that dissolved (soluble) organic P (DOP) becomes the dominant component in these highly treated effluents as the ortho-P being nearly completely eliminated. This residual P fraction is referred as refractory dissolved organic P (rDOP), in a similar way as how the rDON (refractory dissolved organic nitrogen) and rCOD (refractory COD) are defined. The term rDOP is a functional definition rather than a compositional definition. The refractory indicates the fact that it is rather resistant to water treatment processes and the actual chemical composition of rDOP is yet to be further investigated and defined. To further understand the occurrence, fate in and susceptibility of rDOP to different treatment processes, this study conducted a survey of the level of rDOP in various secondary and advanced tertiary P removal processes with the aim to obtain insights in the efficiency and mechanisms for removing various fractions of TP, especially the refractory fraction such as the rDOP, which will provide directions for further optimizing and developing removal alternatives for achieving extremely low effluent TP.

Materials and Methods

Table 1. Evaluated advanced technologies for DOP removal.

Process	Process Description
Conventional Sedimentation	Traditional sedimentation tube settlers with coagulant and polymer addition
DensaDeg Clarifier	Sludge recirculation system combined with a lamella settling tank
CoMag Ballasted Sedimentation	Magnetic powder facilitated ballasted sedimentation process with coagulant and polymer addition
Multimedia Filtration	Multi-media granular media filtration with coagulant chemical and polymer addition
Blue Water Dual-Stage BluePRO™ (DSBP)	Dual-stage continuous- backwash moving bed sand filtration with coagulant chemical addition
Trident HS system	Multi-stage process consists, in series, of up-flow tube-settling clarifier, up-flow coarse floating media contact clarifier and down-flow mixed media filter, alum & polymer addition
Membrane Filtration	Membrane filtration is a filter with pore size smaller than 10 microns
Membrane Bioreactor (MBR)	Biological processes integrated with membrane separation

Conventional P fractionation methods according to Standard Methods (4500-P) are applied to determine the various fractions of phosphorus in treated wastewater samples and the detection limit is 0.002 mg P/L. For now, rDOP is determined as the total dissolved acid-digested P (sTP) minus the dissolved acid hydrolysable P (sAHP) and dissolved reactive P (sRP) in treated effluents. (rDOP=sTP-sAHP-sR

Results and Discussion

Levels of rDOP in various highly treated effluents:

Among the effluents of eight selected advanced tertiary treatment processes, DOP level ranged from 4 to 13 μg/L (Figure 1). The processes that have some level of adsorption effect and multiple barriers/stages, including the DensaDeg clarifier, CoMag ballasted sedimentation, Blue water dual stage filtration and Trident HS system, seemed to be able to remove DOP to a relatively lower level than those that do not. Previous study by Gu et al showed that DOP can be effectively removed by adsorption with various adsorbents. (Gu et al. 2009)

Changes in the DOP percentage through various treatment processes:

Figure 2, 3 and 4 show the comparison of DOP percentage in influents and effluents of sedimentation, filtration and membrane filtration processes. For most of the technologies evaluated, except for conventional sedimentation and Trident HS processes, the percentage of DOP in effluent became higher than those in the influents, as a result of the elimination of other fractions of P such as soluble reactive phosphorus (sRP) and soluble acid-hydrolysable phosphorus (sAHP). For example, for DensaDeg and CoMag effluents, the DOP were 4% and 1% of TP in the influents, but it increased to 19% and 11% respectively in the effluents. Processes that are effective for eliminating other P fractions including particulate and colloidal P and sRP, the increased of DOP fraction in the residual P in the effluents were more pronounced. Membrane microfiltration is the most effective technology on removing particulate forms of phosphorus. As a result, DOP became the dominant fractions (more than 50% of the effluent TP) after membrane filtration.

Conclusions

1. Various advanced tertiary treatment processes have different effectiveness for removing various fractions of P. DOP seems to the most “resistant’ fraction to the applied enhanced sedimentation or filtration technologies since the DOP percentage increased dramatically in these highly treated effluents. Since DOP itself contributed 4 to 13µg/L to the tertiary effluents, in order to achieving extremely low P level (5-10µg/L), removal of DOP must be considered.

2. Other alternative technologies that can target specifically for DOP is desired for further removal of the rDOP. Previous study using adsorption mechanisms showed that adsorption can effectively remove the residual DOP to as low as less than 5-6 µg/L. (Gu et al., 2009)

Reference

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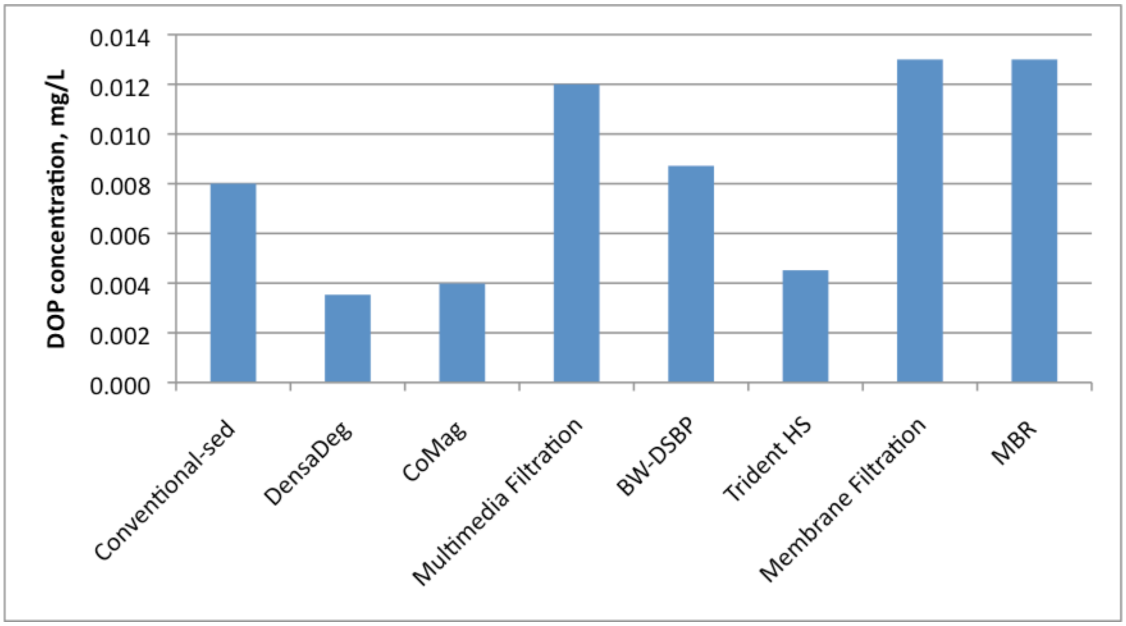

Figure 1. Level of DOP in various advanced treatment process effluent

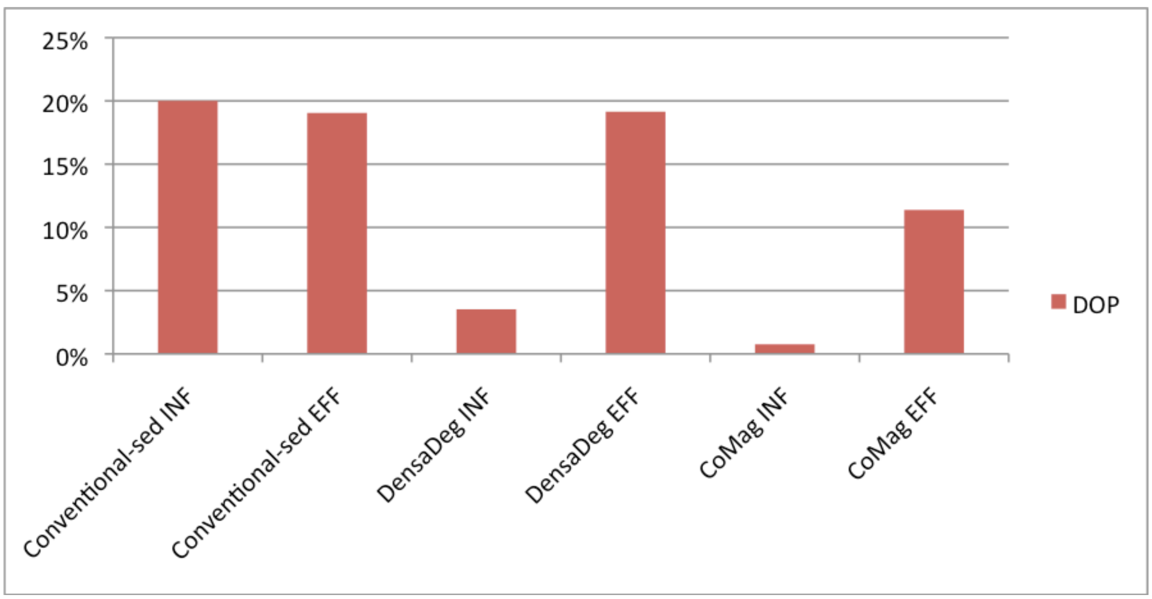

Figure 2. Percentage of DOP of TP influents and effluents from various sedimentation processes

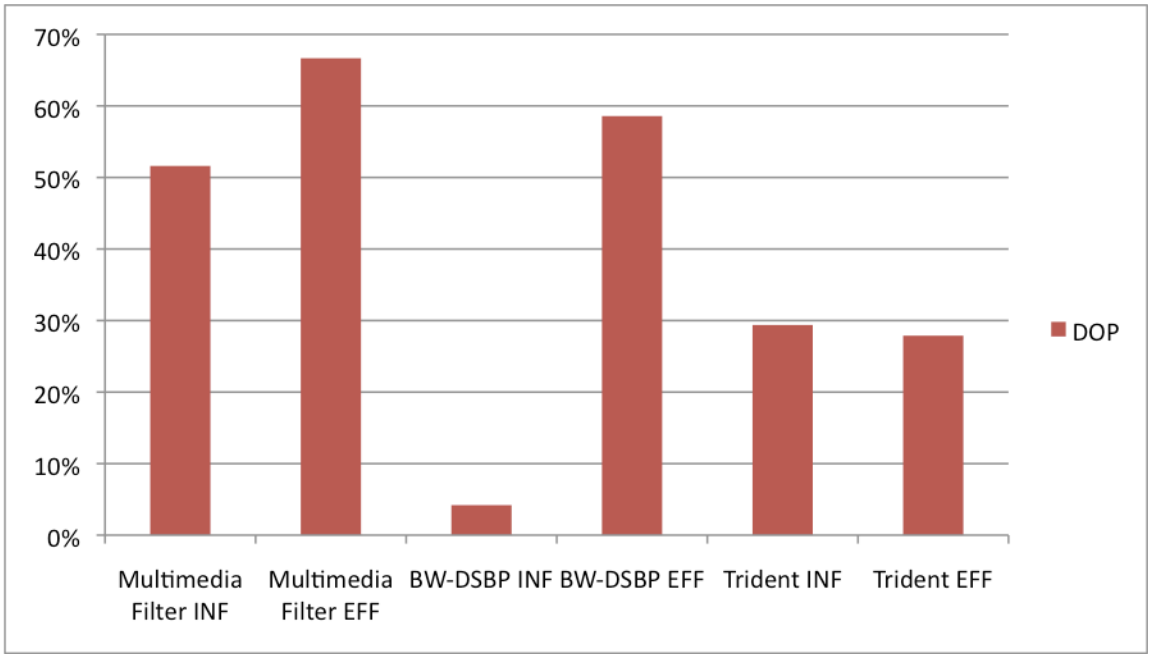

Figure 3. Percentage of DOP of TP influents and effluents from various filtration processes

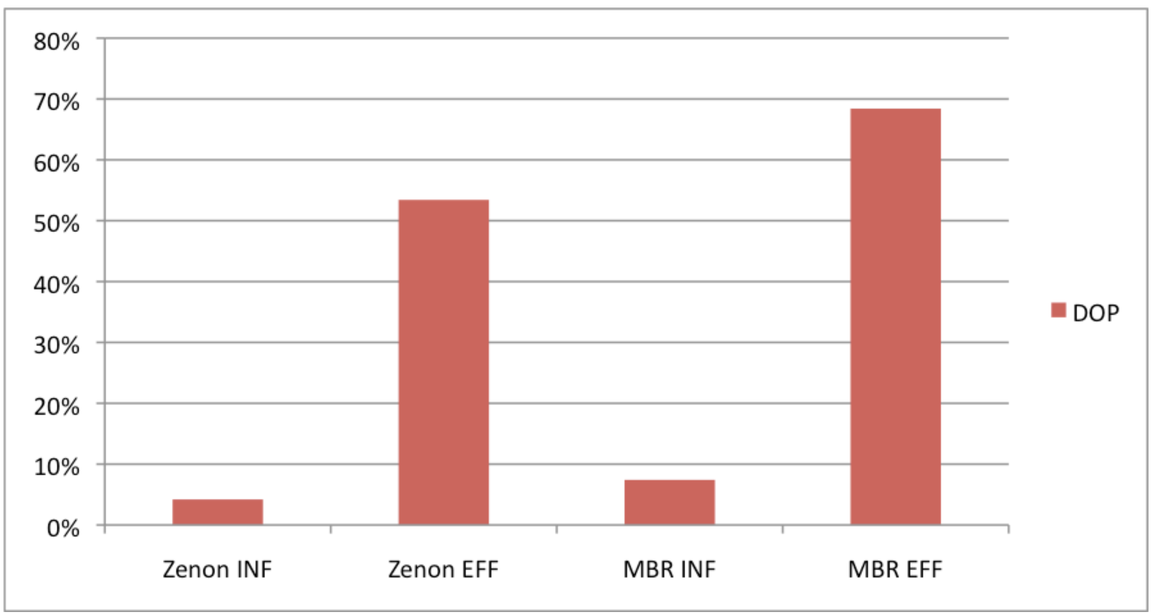

Figure 4. Percentage of DOP of TP influents and effluents from various membrane filtration processes