

## Optimization of Effluent Phosphorus Control For Al-Aziziah (Wasit) Wastewater Treatment Plant

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### Abstract

The combination between the enhance biological phosphorus removal EBPR process and chemical phosphorous precipitation process removal from wastewater to avoid the instability of the biological phosphorus removal process due to temperature variation has been simulated and optimized by implementing three different strategies in the GPS-X 5.0 modeling and simulation software (Hydro mantis). The results were demonstrated that the annual consumption of alum for the three different phosphorus control strategies (side stream line dosing only, wastewater line dosing only and dosing at both wastewater and side stream lines) were 290, 80 and 68 tons Alum/year respectively. Therefore, the implement of both wastewater and side stream lines dosing strategy show a better phosphorus removal choice in terms of effluent quality and amount of alum used.

**Keywords:** combination, biological, chemical, phosphorous, removal.

### المستخلص

الاستخدام المزدوج لعملية المعالجة البيولوجية والترسيب الكيميائي لإزالة مركبات الفسفور من مياه المجاري لتفادي عدم الأستقرارية في طريقة المعالجة البيولوجية بسبب تغير درجات الحرارة تم نمذجتها باستخدام البرنامج GPS-X 5.0 على ثلاثة مقترحات من عمليات الدمج بين طرق الإزالة البيولوجية والكيميائية لاختيار أفضل المقترحات. أظهرت النتائج بأن الاستهلاك السنوي للشب المستخدم للسيطرة على تركيز مركبات الفسفور في المياه المعالجة باستخدام مقترحات المعالجة الثلاثة ( إضافة الشب لخط المياه الراجعة فقط ، إضافة الشب الى خط المياه المعالجة فقط، إضافة الشب الى خط المياه الراجعة والمياه المعالجة) هو 290 ، 80 ، 68 طن سنويا على التوالي. لذلك فإن إضافة الشب الى خط المياه الراجعة والمياه المعالجة يعتبر أفضل الحلول لإزالة مركبات الفسفور من ناحية نوعية المياه المعالجة ومن ناحية كمية الشب المستخدم.

### Introduction

Orthophosphate, polyphosphate and organically bound phosphorus are the main forms of phosphorous in wastewater [1]. In traditional biological treatment of wastewater, about 10% to 30% of influent phosphorus was utilized by organisms during the cell synthesis and energy transport [2], [3], [5]. The biological reaction rate constants depend on temperature variation. Temperature has influences on organisms' metabolic activities as well its effect on such factors as gas-transfer rates and the settling

characteristics of the biological solids [2], [6]. The phosphate accumulating organisms (PAOs) classified as lower range mesophiles or perhaps psychrophiles and predominate at less than or equal to 20 °C [7]. Therefore high summer temperature results in instability of the biological phosphorus removal process. In this case, in-line chemical dosing just before the secondary settling tank and (or) in side stream (supernatant from the sludge treatment units) line which will be operated only if biological removal would be not sufficient would allow to control the effluent phosphorus while keeping the costs for the chemicals as low as possible. The combination between the enhance biological phosphorus removal EBPR and chemical process removal performs better than other choices in terms of effluent quality and alum cost. The chemical process is based on the addition of metal salts reacting with soluble phosphate to form solid precipitates that are removed by clarification. The most common metal salts used are in form of ferric chloride or sulfate, alum and sodium aluminates [8]. The basic reactions involved in the precipitation of phosphorus with aluminum are as follows [8].



Based on equation (1), each 1 kg of phosphorus removed require 0.87 kg of aluminum (31.73 kg alum). This case study illustrates the alternatives of different control strategies for phosphorus removal which can be implemented, in-line chemical dosage on both water and sludge lines at a municipal wastewater treatment project to ensure effluent phosphorus concentration according environmental requirements.

### Case study existing data

The existing plant was an oxidation ditch mechanical secondary treatment plant with an approximate design capacity of average dry weather flow 23486 m<sup>3</sup>/d. Fig. 1 show a GPS-X simulation after adding the phosphorus control for Al-Azeziah wastewater treatment plant. More specific information on the basic design data are provided in Tables 1 and 2.

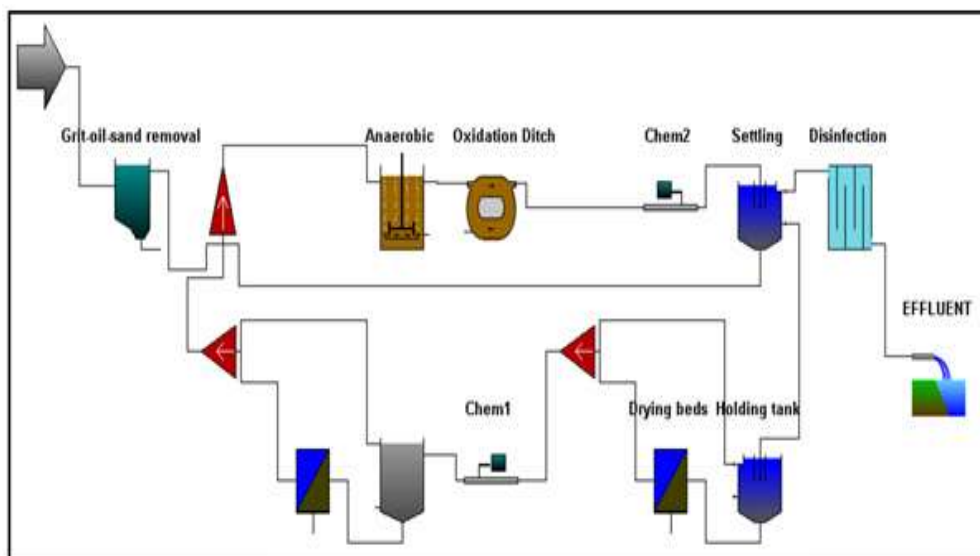


Fig. 1: GPS-X simulation after adding the phosphorus control for Al-Azeziah WWTP

**Table 1: Basic design data.**

Inflow (m <sup>3</sup> /hr.)			Wastewater temperature during the year		
Max.	Average	Min.	Max.	Average	Min.
2188	979	476	34	16	10

**Table 2: Influent and effluent wastewater characteristics**

Influent characteristics (mg/l)						Effluent characteristics (mg/l) according Iraqi rivers protection act number 25 for 1967					
BOD <sub>5</sub>	COD	TSS	TN	NH <sub>4</sub> <sup>+</sup> -N	TP	BOD <sub>5</sub>	COD	TSS	NO <sub>3</sub> <sup>-</sup> -N	NH <sub>4</sub> <sup>+</sup> -N	TP
350	670	400	40	20	8	≤ 20	≤ 100	< 30	≤ 50	≤ 10	≤ 2

### Strategies for effluent phosphorus control

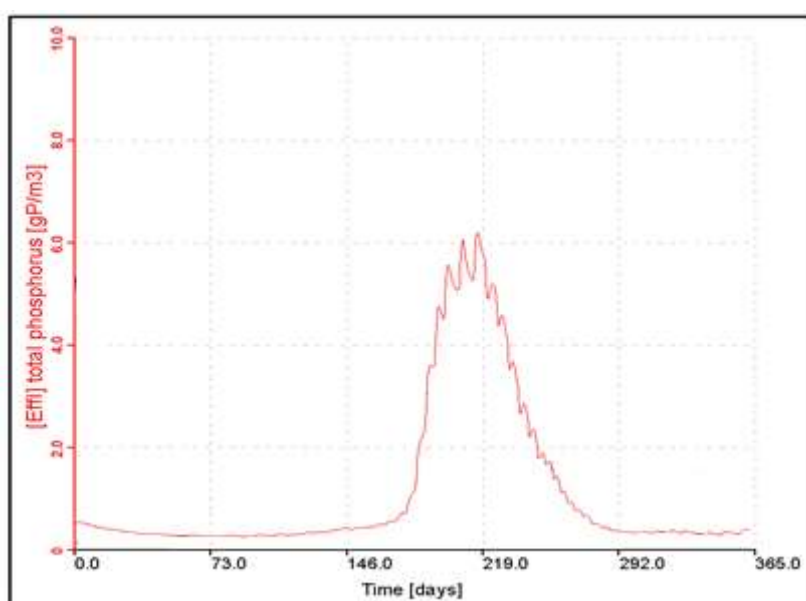
The control of effluent phosphorus concentration can be achieved by dosing chemicals (iron or aluminum salts) in various sections of the plant. It is well known that the occurrence of anaerobic conditions in the sludge treatment line can turn in considerable release of soluble orthophosphate into the supernatant and drainage water. If these streams have to be returned to the water line without any further treatment they can strongly contribute to increase the phosphorus load to the water line [2]. In this case, the dosage of chemicals in all side stream flows to be returned to the water line can be the cheapest option, especially if considering the recovery of a phosphate rich chemical sludge that can be dried separately and sold as fertilizer. On the other hand, it is known that high summer temperature results in instability of the biological phosphorus removal process also in case of separate treatment of side stream from the sludge line. In this case, in-line chemical dosing just before the secondary settling tank which will be operated only if biological removal would be not sufficient would allow to control the effluent phosphorus while keeping the costs for the chemicals low.

In order to ensure the maximum flexibility in future plant operation, in-line chemical dosage on both water and sludge lines is strongly advisable. Based on the above considerations, three different control strategies can be implemented. With the above wastewater plant layout shown in Fig. 1, the following treatment scheme is proposed:

1. Side stream line dosing only (at point Chem1)
2. Wastewater line dosing only (at point Chem2)
3. Dosing at both wastewater and side stream lines (at point Chem1 and Chem2)

## Results

Firstly, the EBPR process design has been simulated and optimized by implementing the proposed plant layout in the GPS-X 5.0 modeling and simulation software (Hydro mantis) in yearly variation of wastewater temperature at average influent flow rate. As shown in Fig. 2, increasing temperature in summer (July and August) leads to a considerable release of phosphorus in the effluent, that can be attributed to a certain instability of the biological process for the removal of phosphorus in the water line, as well as to the increased phosphorus release from the thickening because storage of sludge at higher temperature can favor fermentation processes and creation of anaerobic conditions [3].



**Fig. 2: Simulation results of phosphorus in effluent for EBPR under yearly variation of Wastewater temperature at average influent flow rate.**

### 1. Side stream dosing only (at point Chem1)

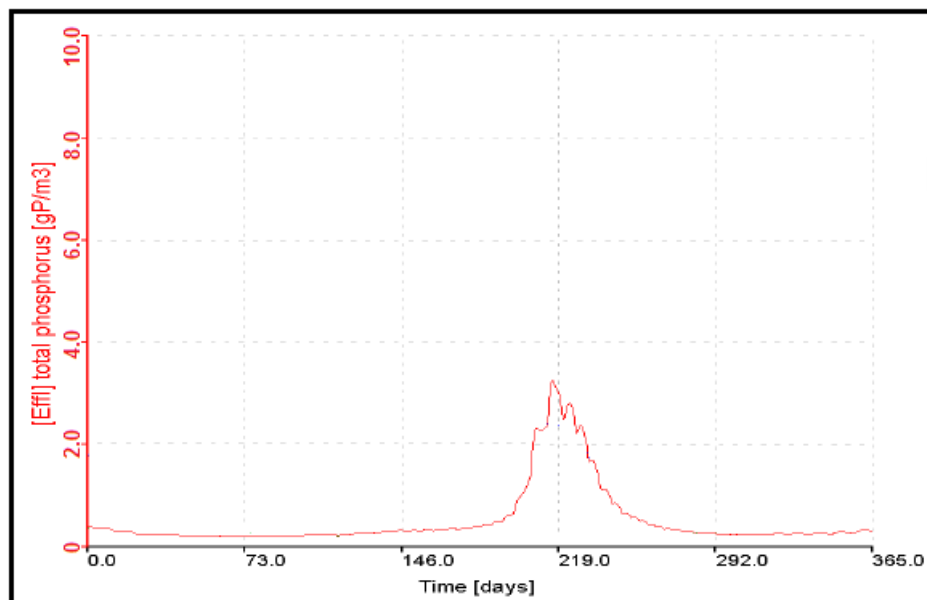
The simulation of the chemical dosing on the side stream line while keeping off the chemical dosing on the water line was demonstrated in Fig. 3. The side stream contains less than 20% of returned phosphorus. The optimal chemical dosage can be estimated to be around 65 kg.Al/d (23.7 ton Al/year), corresponding to a consumption of 0.8 tons of Alum [ $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$ ] per day, with a total annual consumption of about 290 ton Alum/year. Moreover, into account that the phosphorus load to the plant is 188 kg/d, it can be estimated a consumption of (0.35 kg Al/kg  $\text{P}_{\text{influent}}$  (i.e. 4.3 kgAlum /kg $\text{P}_{\text{influent}}$ ) and a molar ratio of 0.4. This value is lower than the typical values of 1 according equation 1 without biological removal. This difference can be attributed to the phosphorus biological removal.

## 2. Wastewater line dosing only (at point Chem2)

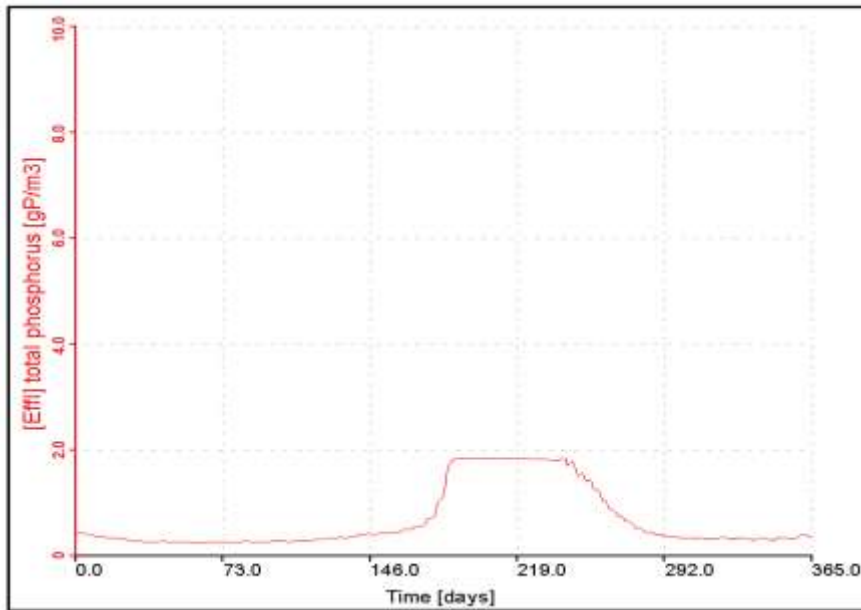
In the Fig. 4 and Fig. 5 the effect of chemical dosing to the wastewater line only is shown, both in terms of effluent quality and chemical dosage to control effluent phosphorus concentration below 2 mg/l. It corresponds to a consumption of 6.4 tons Al/year, in about 2 months and with a maximum dosage of (106 kg Al /d). Similarly to the calculations done in item 1 (i.e. considering a factor of 12.35 kg Alum/kg Al), these dosages correspond to the consumption of about 80 tons Alum/year with a maximum dosage of 1.3 ton Alum/d.

## 3. Both wastewater and side stream lines dosing (at point Chem1 and Chem2)

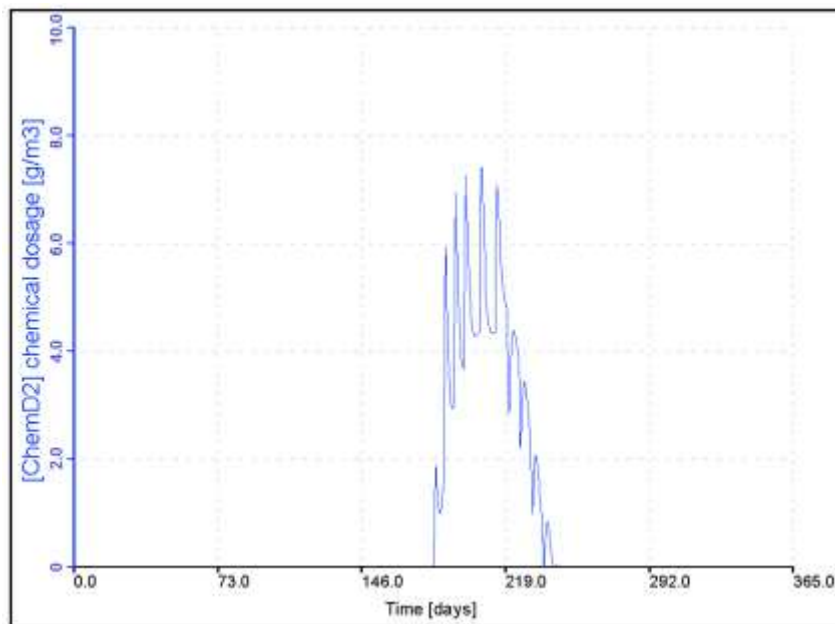
In the Fig. 6 and Fig. 7, a simulation of the effect of the chemical dosage of aluminum salts on both wastewater and side stream lines were shown. From the simulation, the average chemical dosage can be estimated in 60 kg Al/d for about 2 months to the side stream line and 43 kg Al/d for about 1.5 months to the wastewater line with maximum consumption of 134 kg Al/d, with an estimated annual consumption of 5.5 tons Al/year. If Alum is chosen, these dosages correspond to 0.74 ton Alum/d, 0.53 ton Alum/d and 68 ton Alum/year, respectively.



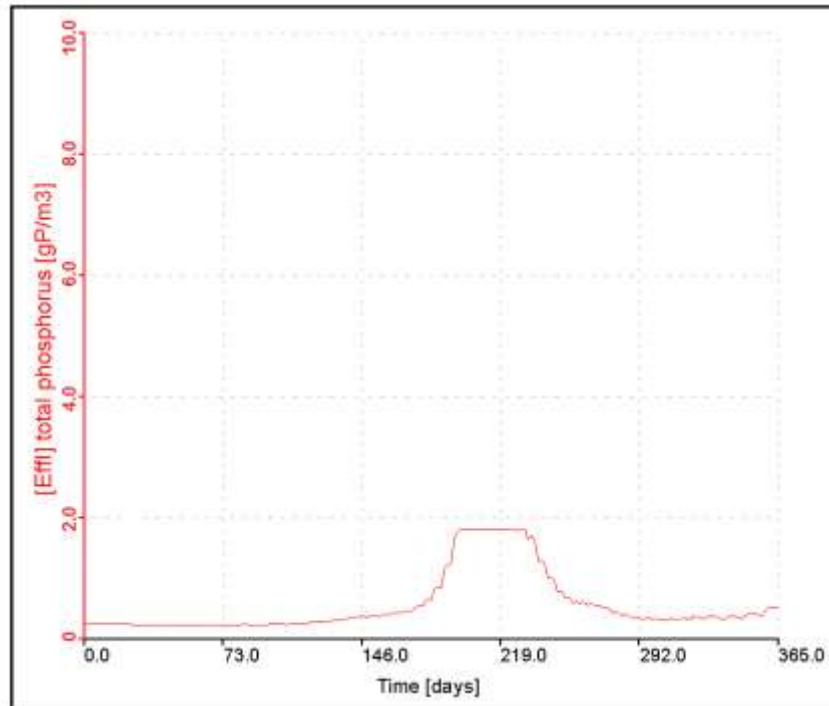
**Fig. 3: Simulation results of phosphorus in effluent under the chemical dosing on the side stream line only.**



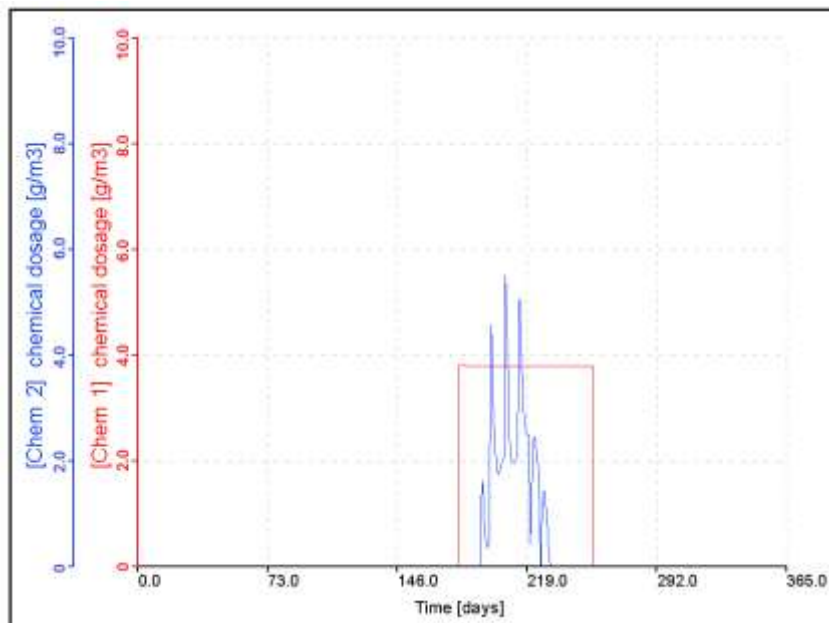
**Fig. 4: Simulation results of phosphorus in effluent under the chemical dosing on the wastewater line only.**



**Fig. 5: Simulation results of the chemical dosing on the wastewater line only to control effluent phosphorus concentration.**



**Fig. 6: Simulation results of phosphorus in effluent under the chemical dosing on the wastewater and side stream lines.**



**Fig. 7: Simulation results of the chemical dosing on the wastewater and side stream lines to control effluent phosphorus concentration**



## Conclusion

There were a considerable release of phosphorus during summer (July and August) because the sensitivity of PAOs to the temperature effect. The combination between the EBPR and chemical process removal was a suitable choice in terms of effluent quality and alum cost. The annual consumption of alum for three different phosphorus control strategies (side stream line dosing, wastewater line dosing only and dosing at) were 290, 80 tons and 68 tons Alum/year respectively. Therefore, the implement of both wastewater and side stream lines dosing strategy show a better phosphorus removal choice in terms of effluent quality and amount of alum used.

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