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Comparison of Chemical and Biological Phosphorus Removal from Wastewater in Numaniya WWTP

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مقارنة بين طرق إزالة الفسفور بيولوجياً وكيمياوياً لمحطة معالجة مجاري النعمانية

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المستخلص
أحد أهداف السيطرة على نوعية المياه السطحية هو تقليل نمو الطحالب فيها بتقليل الفسفور المطروح في البحيرات والأنهار. يزال الفسفور بطريقتين هما الطريقة البيولوجية والطريقة الكيمياوية.
هذه الدراسة أجريت لتقييم كفاءة تصميم محطة معالجة مياه مجاري النعمانية على إزالة الفسفور ومقارنة بين مزايا استخدام كل من الطريقتين البيولوجية والطريقة الكيميائية لأزالة الفسفور. أظهرت الدراسة أن الجمع بين الطريقة البيولوجية والطريقة الكيمياوية لأزالة الفسفور هو الأختيار الأفضل لمحطة معالجة مياه مجاري النعمانية من ناحية نوعية المياه المعالجة المطروحة للنهر ومن ناحية توفير كلف استخدام مادة الشب.

Abstract

The water quality management for surface water aims to reducing the eutrophication by controlling and reducing the input phosphorus to the lakes and waterways. Two methods are currently being used around the world to remove phosphorus in wastewater: biological and chemical phosphorus removal.

This study was conducted to predict and compare the efficiency of phosphorus removal between designed biological process for Numaniya WWTP and chemical process as well as EBPR plus chemical process. Results obtained from the study demonstrate that combination between the EBPR plus chemical process removal performs better than other choices in terms of effluent quality and alum cost .

Introduction

Phosphorus is usually the limiting nutrient for eutrophication in land receiving waters from waste water treatment plant; therefore, phosphorus concentrations in effluents must be controlled [1]. As the algae die, the settle in the waterway bottom, where the are decomposed by benthic organism which is sufficient to deplete the hypolimnion of oxygen leading to the death of other organisms in surface waters [2]. The death of organism cannot be stopped simply by minimizing the amount of phosphate (and nitrate) discharged into wastewater by industrial and agriculture activities, since the phosphate derived from human metabolism alone is sufficient to sustain the eutrophication process. Therefore, it is essential to remove phosphorus efficiently from wastewater [3].

Beginning from 1970s phosphorus removal from wastewater has been recognized as one of basic processes necessary to be done in all wastewater treatment plants. In this paper trends and directions of development of phosphorus removal from municipal wastewater in Numaniya WWTP which is under construction has been presented , in addition to describe technologies of enhanced biological removal plus chemical precipitation. In the biological phosphorus removal, the main actors are the polyphosphate accumulating organisms (PAOs) whose ability to take up large amounts of phosphorus from phosphates by exposing them to alternating anaerobic and anoxic/aerobic conditions is exploited. The resulting activated sludge becomes enriched in a bacterial population with the capability to take up phosphate in excess and store it as polyphosphate, under aerobic conditions. In this process, phosphorus is not removed only, but also the organic content in the waste stream is considerably reduced.

In chemical phosphorus removal, a metal salt (usually aluminum and iron salts) is used to convert the dissolved inorganic phosphorus compounds in the wastewater into a low solubility metal phosphate which can be removed in the subsequent sedimentation stage of an activated sludge process.

Aims and methods

The aims of this papers is to verify possible option to develop the designed process of Numaniya WWTP which consist oxidation ditches following by secondary clarifiers, to achieve the phosphorus removal from wastewater. The study assumed the plant with steady state operation in average conditions of influent flow, load and temperature. Phosphorus appears in wastewater as orthophosphate, polyphosphate and organically bound phosphorus, the last two components accounting usually for up to 70 percent of the influent phosphorus. Microbes utilize phosphorus during cell synthesis and energy transport. As a result, 10 to 30 percent of the influent phosphorus is removed during traditional mechanical/biological treatment [4,5]. A significant removal efficiency can be achieved by both enhance biological phosphorus removal EBPR or chemical precipitation.

Enhance Biological Phosphorus Removal EBPR

The EBPR is based on the introduction of an aerobic tank in which the growth of phosphorus accumulating organisms PAO is favored. These bacteria are apple to store phosphates into the cell when sequence of anaerobic and aerobic conditions is achieved. In case of oxidation ditch, the process configuration described can be applied by adding an anaerobic tank in which recycled sludge is mixed with influent waste water before the oxidation ditches. The hydraulic retention time for the anaerobic tank should be maintained between 1 to 2 hours. The amount of phosphorus removed by biological storage can be estimated from the amount of biodegradable soluble chemical oxygen demand bsCOD that available in the wastewater influent as most of the bsCOD will converted to acetate in the short hydraulic detention time. About 10 gm of bsCOD will be required to remove 1 gm of phosphorus by the biological storage mechanism [5]. The influent bcCOD is usually considered in the range 10-30% of the influent BOD, however, part of this COD is consumed for de-nitrification of the nitrate coming with the recycled activated sludge (RAS) where 1.0 mg nitrate denitrified required 2.86 mg of COD. Considering the nitrate concentration in the RAS 10 mg/l for Numaniya WWTP. The sludge biomass typically contains 1-2% phosphorus on dry weight basis([1]). The amount of phosphorus in effluent can be estimated by:

$$\mathbf{P_{x.bio} = MLVSS \times \frac{V}{SRT} - Q \times nbVSS} \ \ldots\ldots\ldots\ldots\ldots\ldots \ \mathbf{(1)}$$

When:

MLVSS=mixed liquor volatile biomass=2.5Kg/m^3

V= volume of oxidation ditches =28500m^3

SRT=solid retention time =21d

nbVSS= non-biodegradable volatile= 0.03Kg/m^3

$$P_{effluent} = P_{in} - \left(\frac{rbCOD - 10\times 2.86}{10}\right) - \frac{P_s}{Q} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Increased sludge production is usually considered 3 gm suspended solid SS for each 1 gm of phosphorus removed.

$$\Delta Q_s = P_{biological\ removed} \times 3 \times Q \ \ldots\ldots\ldots\ldots\ldots (3)$$

Phosphorus removal by chemical precipitation

The physical – chemical process (precipitation and settling) 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. The process configuration that can easily applied in Numaniya WWTP . the metal salt is dosed before the secondary settling tank and the chemical sludge is removed together with excess activated sludge.

The basic reactions involved in the precipitation of phosphorus with aluminum are as follows[5].

$Al^{+3} + H_nPO_4^{-3} \rightarrow AlPO_4 + nH^+$ phosphate precipitation with aluminum………(4)

$Fe^{+3} + H_nPO_4^{-3} \rightarrow FePO_4 + nH^+$ phosphate precipitation with iron………………(5)

With addition of 1.5kg iron, a sludge production of 6.6 kg for each kg phosphate removed. The minimum chemical sludge production can be estimated as follows:

$$\Delta Q_s = [Q(P_{in} - P_e) - Ps)] \times 6.6 \quad \ldots\ldots\ldots\ldots\ldots\ldots(6)$$

Comparison based on effluent quality

The discharge limits of the Numaniya WWTP are set based on total phosphorus concentration are listed in (Table1). The effluent quality estimated by calculation are listed in (Tables 2). From the results obtained, it was observed that the effluent qualities in terms of chemical process and EBPR plus chemical process are within the discharge limits. EBPR plus chemical process was observed to reach a minimum of 1.77 mg P/l in the effluent.

The effluent phosphors concentration and sludge production for designed biological, chemical and EBPR plus chemical processes have been tabulated (see Table 2). From the table it is observed that chemical phosphorus removal produces more sludge than designed biological process. From a quantitative analysis of the results, chemical phosphorus removal (alum) and EBPR plus chemical process produces about 11% and 12% more sludge per day than designed biological process respectively. The production of sludge is considered a very important factor in the choice of a wastewater treatment method nowadays. This is further complicated by the fact that in countries use of sludge from wastewater treatment plants as a fertilizer for agriculture. Also, it is observed that chemical phosphorus removal consume alum about 46 times that consumed by EBPR plus chemical process. Figure (1) gives the Schematic diagram of biological – chemical phosphorus removal process.

Table 1: Characteristics of the discharge at Numaniya WWTP

Parameter	**Influent**	**Effluent**
Flow (m^3/d)	**25220**	**25220**
Tot-P (mg/l)	**8**	**2**
Temp (^oC)	**16**	**16**

Table 2: Overall treatment efficiency for biological and chemical methods.

Parameter	P_{tot} mg/l	Sludge production kg/d	$\frac{\Delta Qs}{Qs}$	Chemical dosing kg/d
Chemical process (alum)	2.0	6389	0. 11	3713
Bio-P + chemical	1.77	6407	0. 12	80.04
process without P removal	5.91	5738	-	-

Conclusion

1. It is not a good idea to state that any phosphorus treatment method is better than the other. Each one has its own advantages and disadvantages. The choice of which method is to be used will depend on the society, the discharge requirements and the costs they are ready to incur.As a final conclusion, the winning concept these days should not be based on which process should be used in isolation to the other, but rather using the advantages of both processes together to obtain best results, while at the same time minimizing their disadvantages.
2. For Numaniya WWTP , EBPR use to remove the phosphorus from the influent as well as, chemical phosphorus removal for supernatant of holding tanks and drainage water of drying bed before return to the beginning of the process is the optimum solution to develop phosphorus removal of Numaniya WWTP.
3. Combination the EBPR plus chemical phosphorus removal performs better in terms of effluent quality and saved the daily amount of 3.713 tons of alum is required to treat wastewater to discharge limits in case of using the chemical phosphorus removal.

Notation

WWTP : Waste Water Treatment Plant.
EBPR ; Enhance Biological Phosphorous Removal.
PAOs : Polyphosphate Accumulating Organisms.
bsCOD : biodegradable soluble chemical oxygen demand.
RAS : Recycled Activated Sludge.
BOD: Biochemical Oxygen Demand.
COD: Chemical Oxygen Demand.

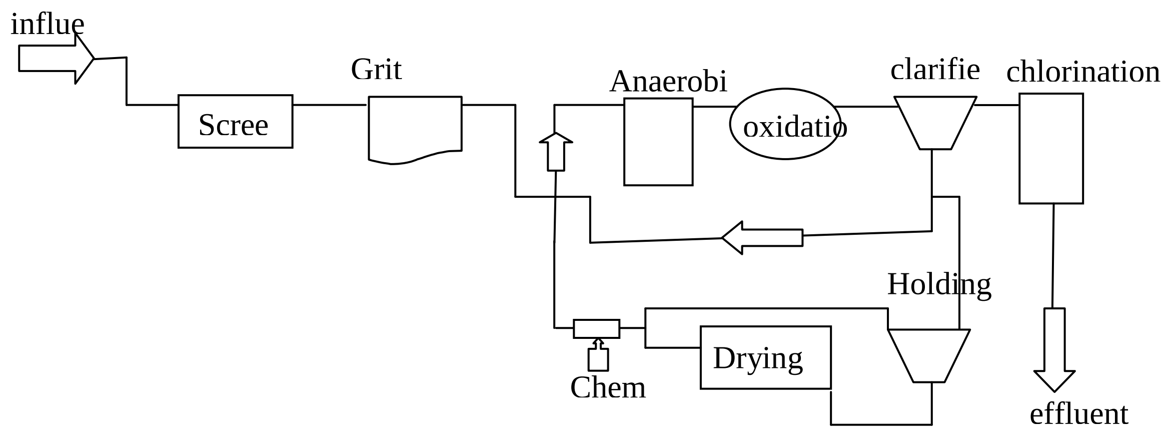

Figure (1): Schematic diagram of biological – chemical phosphorus removal process

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