Pol. J. Environ. Stud. Vol. 23, No. 3 (2014), 831-834

Original Research

A Survey on Nitrogen and Phosphor Compound Variation Processes in Wastewater Stabilization Ponds

Meghdad Pirsaheb[1], Mehdi Fazlzadehdavil[2]*, Sadegh Hazrati[2], Kiomars Sharafi[1], Tarokh Khodadadi[1], Yahya Safari[3]**

[1]Department of Environmental Health Engineering, School of Public Health, Kermanshah University of Medical Sciences, Kermanshah, Iran
[2]Department of Environmental Health Engineering, School of Public Health, Ardabil University of Medical Sciences, Ardabil, Iran
[3]Department of Public Health, School of Public Health, Kermanshah University of Medical Sciences, Kermanshah, Iran

Received: 13 November 2012
Accepted: 2 October 2013

Abstract

Being economical has increased utilization of stabilization ponds to remove different contaminants from wastewater in proper weather conditions. Our current study investigates variations of nitrogen and phosphorous compound concentrations in effluent of wastewater stabilization ponds. 60 samples were taken from raw wastewater, anaerobic pond (AP) effluent, primary and secondary facultative ponds (PFP and SFP), and effluent of final ponds in weekly intervals for 3 months. Samples were examined based on standard methods (20th edition) for the examination of water and wastewater. Nitrogen kjeldahl removal output due to the AP, PFP, SFP, and the whole system were 20.6±4.9, 6.6±3.4, 13.4±9.5, and 47.7±9.1%, respectively. Nitrite removal output due to the PFP, SFP, and the whole system were 30.1±8.8, 36.3±9.8, and 58.8±5.2%, respectively. Respective values for phosphor removal output in AP and SFP, and the whole system were 21.8±10.3%, 13.3±10.1%, and 20.9±17.1%. However, nitrite concentrations in all samples from AP effluent and phosphor levels in all samples from PFP effluent increased compared with those of influent. The results showed that AP plays an important role in removal of organic nitrogen and phosphorous compounds. While the whole system output in nitrogen compound removal was 58.8±5.2%, phosphor removal output showed low efficiency (20.9±17.1%). Increasing the number of complete ponds is suggested for increasing phosphor removal efficiency.

Keywords: nitrogen compounds, phosphor, stabilization ponds, wastewater treatment

Introduction

Raw municipal wastewater includes nutrients of nitrogen and phosphor compounds. Discharging these contaminants to the environment can cause eutrophication phenomenon in received waters, followed by algal and plant growth in shallow rivers. This may cause aesthetic issues as well as some other problems in water use, especially for domestic and recreational purposes. In addition, high solubility of ammonia in water may influence aquatic life, especially fish reproduction. Eutrophication phenomenon can

*e-mail: m.fazlzadeh@gmail.com
**Corresponding author

Table 1. Characteristics of primary and secondary facultative ponds in two parallel series.

Type of pond	Width (m)	Length (m)	Depth (m)	Overload (kg BOD/ha)	Area (m^2)	Volume (m^3)
Anaerobic	78.8	100	4	–	7,880	24,768
Primary facultative	95.6	710.4	1.54	180	67,914.2	104,588
Secondary facultative	97	343	1.5	87	33,271	42,219

also affect the disinfection process (especially chlorination), leading to some diseases such as methemoglobinemia and cancers [1-3]. Thus, it is necessary that wastewater be treated prior to discharge into the environment. Different methods used to remove nitrogen compounds from wastewater include nitrification, denitrification, dissolved air floatation, chlorination to breakpoint, ion exchange, and reverse osmosis [4-7], which found a low application because of their cost, requiring chemical addition and producing toxic compounds [7]. However, biological methods are rather inexpensive for nitrogen and phosphor compound removal. Recent experiences have shown the biological processes to be effective methods on nutrient, especially nitrogen, removal. They can be considered as a suspended growth system in which the microorganisms – as conversion agents – are kept suspended and organic compounds of wastewater are converted to CO_2 or microbial yield [8, 9].

One of the methods for biological treatment of wastewater to remove nutrients is a wastewater stabilization pond (WSP) [10]. In this system nitrogen removal occurrs through absorption by algae, removing by settling, and adsorption by soil. The main mechanism, according to recent studies, is nitrogen going out to the atmosphere in the form of gaseous ammonia. However, mechanisms responsible for phosphor removal in stabilization ponds are absorption by algae and chemical sedimentation. Efficiency of phosphor absorption by algae is lower than nitrogen removal, since algae consumes nitrogen 10 times more than phosphor compounds [3, 11, 12].

Assessment of wastewater biological treatment system efficiency on nutrient removal and their variation process in different treatment levels are very important for the purpose of good maintenance and effluent quality promotion [13]. Therefore, we aimed to identify the nitrogen and phosphor compound variation process due to the stabilization pond series in Islamabad Gharb.

Materials and Methods

Study Site

Islamabad Gharb is located between northern latitudes 34º-6′ and 34º-7′ and western longitudes 51º-4′ and 51º-33′ in northwestern Iran. The city is situated at an altitude of 1,330 to 1,380 meters above sea level and has a predominantly semi-arid desert climate. The wastewater treatment plant in Islamabad Gharb was originally constructed in 2005 and consists of six stabilization ponds in two modules operated in parallel. The ponds in each module were arranged in three stages, 1 anaerobic pond (AP) as the first stage followed by 1 primary facultative pond (PFP) and 1 secondary facultative pond (SFP) (Fig. 1). Design characteristics of PFPs and SFPs are given in Table 1. The present wastewater treatment facility currently handles 27,000 m^3 sanitary sewage per day (13,500 m^3 per day per module) produced by 90,000 people. It has been projected that the plant will fulfill wastewater management needs for 120,000 people in the future.

Sampling

Sixty samples were taken from raw wastewater, AP, PFP, SFP, and the final pond effluent (after chlorination) at weekly intervals in summer. TKN (Total Kjeldahl nitrogen), nitrite, and phosphor levels were determined based on standard methods for the examination of water and wastewater, No. 4,500 [14]. Wastewater sampling and transferring of the samples to laboratory were done according to standard methods [14].

Results and Discussion

The results show considerable differences in nutrient removal in various point of WSPs (Fig. 2). Kjeldahl nitro-

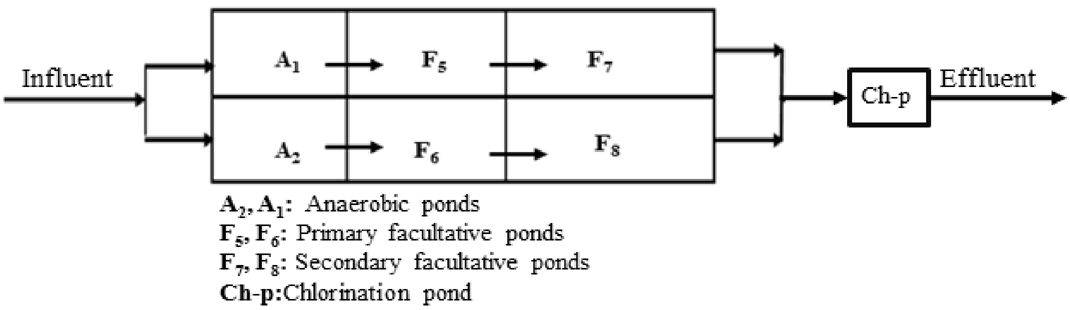

Fig. 1. Schematic diagram of the Islamabad Gharb stabilization ponds.

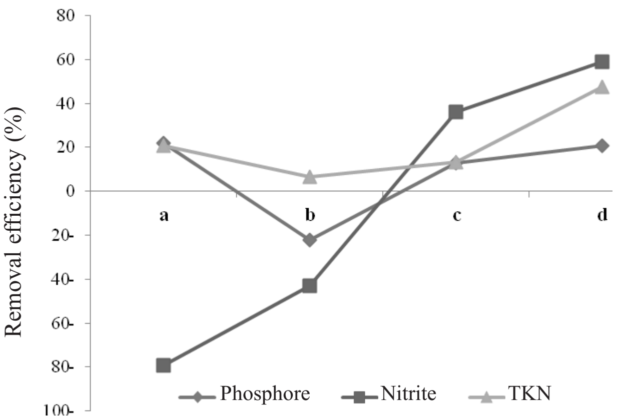

Fig. 2. Kjeldahl nitrogen, nitrite, and phosphor variation process in Islamabad gharb WSPs: (a) anaerobic pond, (b) primary facultative pond, (c) secondary facultative pond, (d) whole system.

gen removal output of 20.6±4.9, 6.6±3.4, 13.4±9.5, and 47.7±9.1% were obtained for APs, PFPs, SFPs, and the whole system, respectively. Nitrite removal by PFPs, SFPs, and the whole system has been obtained as 30.1±8.8, 36.3±9.8, and 58.8±5.2%, respectively. However, nitrite levels of the samples taken from AP effluent were higher than those of influent at the first stage (Figs. 3 and 4).

Phosphor removal efficiency of 21.8±10.3, 13.3±10.1, and 20.9±17.1% were obtained for APs, SFPs, and the whole system, respectively. However, phosphor levels increased in all samples from PFP effluent relative to those of influent.

Organic nitrogen removal mostly occurred in AP, possibly due to nitrogen mineralization and its sedimentation [13, 15]. In addition, hydrolysis to ammonia interferes in decreasing the organic nitrogen concentration in AP [3]. Increasing nitrite levels in AP effluent was observed due to an anoxic situation that causes the transformation of nitrate to nitrite.

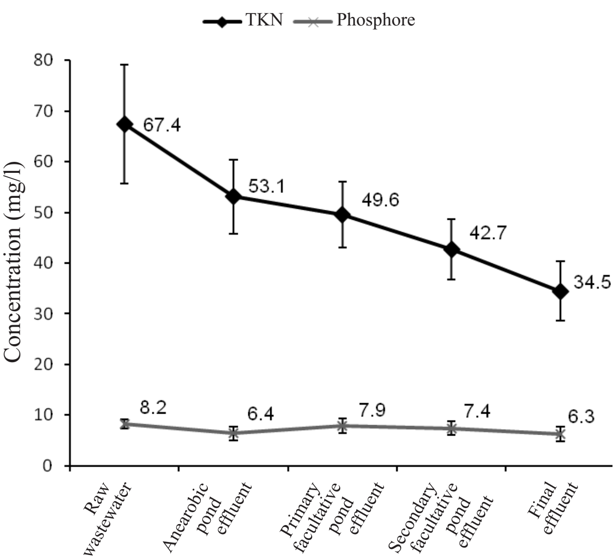

Fig. 3. Variation of TKN and phosphor concentrations at different points (locations).

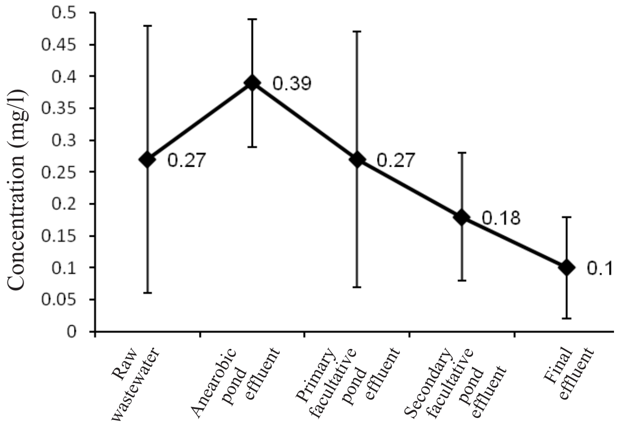

Fig. 4. Nitrite concentration variation at different points.

Other mechanisms for nitrogen removal in FPs are nitrification and denitrification processes. At first, ammonia is converted to nitrite and nitrate due to the nitrification process in aerobic levels of ponds, leading to a decrease in nitrite concentration. Nitrate produced is used by algae and they settle at the bottom of ponds after death. About 20% of algal bodies are non-biodegradable, which makes the nitrogen remains unsolvable in the pond sediments. However, the nitrogen in biodegradable parts of algae is returned to wastewater in the form of dissolved nitrogen [3, 11]. For that reason, nitrogen compound concentrations have a big variation in pond effluent, and measuring the nitrate level in pond effluent is less important. Also, some parts of nitrate produced in anaerobic or anoxic layers are converted to N_2 due to the denitrification process and then released to the atmosphere.

Soares et al. in 1996 showed that the WSPs had low efficiency in nitrogen removal [16]. Similarly, in the current study kjeldahl nitrogen removal rate with WSPs was not considerable.

Ammonia is converted to the new algal mass in facultative and complete ponds. Santos and Oliveria studied nitrogen transformation and removal in WSPs anaerobic, facultative and complete ponds in three series. They found that AP was the most important place for organic nitrogen removal, which is in line with the current study results. Also, it has been shown that more ammonia removal occurs in facultative ponds. In addition, it was shown that biological removal of nitrogen frequently occurred in summer [13]. Lai and Lam in Australia surveyed the main methods for nitrogen removal in WSPs and concluded that the more nitrogen removal occurred at highest detention times, high oxygen, and high chlorophyll conditions [17].

Amargo and Mara showed that the TKN, ammonia, nitrite, and nitrate removal efficiency in all APs, PFPs, and SFPs were less than 71%, reaching to 90% after complete pond [18]. Nevertheless, in the current study, TKN and nitrite removal are less than those results that may be due to application of ponds in different weather conditions, inlet wastewater characteristics, and designing issues.

Similar to nitrogen removal, most phosphorous removal occurred in AP possibly because of sedimentation mechanism due to the high detention time [3, 11]. Phosphor removal of the whole system was equal to 20.9±17.1%. However, Ghazy et al. had reported a removal output of 68.4% [10]. According to the different research results, AP efficiency in phosphor removal isn't considerable and that setting the complete ponds after facultative ponds has been suggested to remove most of the phosphor in WSP system, the phosphate amounts in the WSP effluent have a decreasing process with the facultative SPs, especially SFPs, having the most effect [3].

Total phosphor removal in WSP depended on the level of entering phosphor to the pond sediments and also its remaining time in wastewater. In facultative ponds, the sedimentation removes some parts of phosphor in the organic form in algal masses. Other parts of settled phosphor return to wastewater due to mineralization and re-dissolution. This is confirmed by the current study, since the phosphor amounts were increased in PFP effluent. Remaining phosphor in non-biodegradable parts of algae, like nitrogen, will remain. Therefore, the most effective method for phosphor removal in WSPs is increasing complete pond numbers [3, 11].

Conclusion

The results showed that AP plays an important role in removal of organic nitrogen and phosphorous compounds and, similar to nitrogen removal, the most phosphorous removal occurred in AP. While the whole system output in nitrogen compound removal was 58.8±5.2%, the phosphor removal output showed low efficiency (20.9±17.1%). Therefore, increasing the number of complete ponds is suggested for increasing phosphor removal efficiency.

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