Wastewater treatment efficiency in stabilization ponds, Olang treatment plant, Mashhad, 2011-13

Hadi Rahmatiyar [1], Elham Rahmanpour Salmani *[2], Mohammad Reza Alipour [3], Hossein Alididi [1], Roya Peiravi [1]

1) Health Sciences Research Center, Department of Environmental Health Engineering, School of Health, Mashhad University of Medical Sciences, Mashhad, Iran
2) Research Committee, Department of Environmental Health Engineering, School of Health, Mashhad University of Medical Sciences, Mashhad, Iran
3) Mashhad Water and Wastewater Company

**Author for Correspondence: Rahmanpoure1991@gmail.com*

Received: 9 Nov. 2014. , Revised: 21 Dec. 2014, Accepted: 27 Dec. 2014

ABSTRACT
Olang wastewater treatment facilities purifying raw urban wastewater consist of two stabilization pond modules. Both are on operation in parallel. Functioning of natural systems is influenced by different factors including ambient condition. Considering final effluent of this system discharges to Kashafrood river and sometimes is used for agricultural purposes, assessing the quality parameters in effluent was the main objective of this study. This cross-sectional study investigated some important quality parameters for both raw and treated wastewater in two years periods. Data analysis was carried out using descriptive statistics. Statistical tests were done at a significant level of 0.05. Simple linear regression analysis was used only for modeling. Raw wastewater was almost severe.
Average removal efficiency for BOD5, COD, and TSS was 81, 83, and 78% respectively. There wasn't a meaningful relationship between the removal efficiency of mentioned parameters and input pH. Ambient temperature fluctuations were effective on BOD5, and COD reduction. SAR index didn't show a considerable restriction on irrigation application of effluent. In 62.5% cases outlet Na content was at the extent to which restrictions were imposed.
Olang wastewater treatment plant generates an acceptable effluent relating to most of the quality parameters that were measured in this study. Considering special status of Mashhad city, it is worthy to reuse effluent in areas with a high water requirement such as agriculture.
Key words: Irrigation, Natural Treatment, Performance,Seasonal Variations, Stabilization Pond

INTRODUCTION
Waste generation in huge amounts is the inevitable result of the development of modern societies. Wastewaters are hazardous for human life and have adverse effects on the natural environment. Thus preserving the natural environment, and water resources and preventing them from being contaminated by wastes generated through human activities, has a vital importance and wastewater treatment before discharge and disposal of surface water resources is necessary [1, 2]. There are very different methods for wastewater treatment that mainly classify into two categories: conventional methods, and natural processes. Conventional treatment systems are including trickling filters, activated sludge, rotating biological contactors (RBC), and aeration lagoons [3]. These plants because of their high construction expenses, maintenance intensity and skilled personnel requirement are widely used for wastewater treatment just in the developed countries. Developing countries prefer alternative systems that don't burden a remarkable cost, and provide an effective, reliable and sustainable way of treating wastewater. One of these alternatives can be waste stabilization ponds (WSPs). This method is a well-established one for wastewater treatment in tropical and subtropical regions [4]. WSPs are commonly used because of their low capital and operating costs, simplicity of operation and maintenance, and their capability to handle fluctuating organic and hydraulic loads [5, 6].WSPs have been extensively used in the world for treating wastewater, particularly for small towns and developing communities [5, 7, 8].The main obstacle of this type of treatment is the high amount of suspended solids (SS) in effluent mostly due to high concentrations of algal cells [5, 6]. The system overall consists of a series of anaerobic, facultative and maturation ponds, with wastewater retention

time about 5 to 20 days and depending on the pond type. Depth is usually 1-3 m [9, 10]. WSPs are biological treatment systems in which the processes and operations are highly dependent on the environmental conditions [11] such as sunlight, wind, temperature, rainfall and evaporation [12-14]. Pirsaheb *et a.l* in their study showed "agricultural land irrigation with olang treatment plant effluent compared with well water had better effect in the wheat yield and if a continuous monitoring is done effluent can be a good alternative to water in order to irrigate" [15]. Almasi *et al.* in assessment the performance of anaerobic stabilization pond in the removal of phenol from oil refinery wastewater of Kermanshah city showed that the efficiency of system in removal of phenol, $TBOD_5$, and TCOD was 89.82, 71.75, and 74.99 percent respectively. They also indicated that anaerobic stabilization ponds in the removal of phenol and other organic compounds in the oil refinery wastewater have high efficiency [16]. In a two-year study conducted by Muga *et al.* in Bolivia, they found that facultative and maturation ponds had a proper performance in organic load reduction [17]. Mashhad the center of the Razavi Khorasan province is a metropolis in northeastern Iran. According to the last General Population and Housing Census in 2011 Mashhad populations as the second most populous city in Iran after Tehran are 2,766,258.It also welcomes over 32 million home visitors and more than one million foreign visitors annually. With respect to fall in groundwater resources of Mashhad which are the primary supply for drinking, industrial, and agricultural usages, and considering the fast development in the agriculture industry, wastewater effluent reuse can play an important role to cover the water needs of this region. The aim of this study was to evaluate the performance of Mashhad Olang stabilization pond wastewater treatment system and the quality of effluent on the basis of the parameters recommended by the Iranian Department of Environment (IDE).

MATERIALS AND METHODS

Site Descriptions

Olang wastewater treatment plant (OWTP) of Mashhad is located in the east of the city, in the south of Kashafrood River. Its area is approximately 600 ha and is expandable to 900 ha. The pond's altitude is 890 m above sea level. Figure1 represents an overview of the treatment plant. The system has started its operation in 2002. OWTP uses stabilization pond method and its design treatment capacity is 25000m3/d. The system receives sewage from east of Mashhad where most of the city hotels and commercial centers located, furthermore the amount of industrial flow coming to the system is negligible.

In initial designing for OWTP 4 complexes were considered and until now, 1 complex is constructed completely. The complex comprises 2 modules. Every module includes: 4 anaerobic digestion pits, 2 facultative lagoons and 1 maturation pond. Physical and operational parameters of the OWTP system are summarized in table1.

Fig.1: Overview of treatment plant

Table 1: Physical and operational characteristics of OWTP

Parameter	DP	FL	MP
Hydraulic retention time (day)	1.5	16.5	8
Pool depth(m)	5	4	5
area of the Ponds Bottom (m^2)	-	31000	24000
Slope walls	1to3(Vertical to horizontal)	1to3(Vertical to horizontal)	1to3 (Vertical to horizontal)

DP: digestion pits, FL: facultative lagoon, MP: maturation pond

A bypass channel is considered at entrance to transfer extra volume of sewage especially when rainfall occurs in Kashafrood River. The type of screen is manual and there isn't a grit chamber, so grits constitute a considerable part of sludge volume in ponds. Inputting flow after crossing the screening unit and partial flume channel goes to 2 anaerobic digestion pits that are embedded in the floor of any facultative lagoon. Wastewater flows among these pits are upward and eventually begin to enter the facultative lagoons. Digestion pits diagram is like an inverted pyramid. This type, of designing causes falling in by sewage rate and lead to deposition of suspended particles in pits. The major part of the organic load will be stabilized in digestion pits. There is not any special facility for sludge disposal in the plant, maybe because it takes a long time to sludge forms in the stabilization pond method. Effluent goes out of the system completely and there is no waste turning back to OWTP. Finally the treatment plant effluent is discharged into Kashafrood River, and in downstream it is used for irrigation and agricultural purposes.

Sample Collection

This was a cross-sectional study carried out during a two-year period from a few days before April 2011 to late March 2012 and the same as next year (these dates introduce a complete year in Iran that starts with spring). Weekly sampling was done and a monthly mean of the results recorded. Inlet samples were taken at 8 am, 12, and 4 pm and then mixed. Composite samples from inlet and grab samples from the outlet collected in a volume of 2L. Then samples transferred to water and wastewater chemical lab of Mashhad Health College. All the sampling, sample transfer and analysis were carried out according to standard methods for the examination of water and wastewater.

Weather Conditions

In general, the climate of Mashhad city is moderate and cold mountainous. The maximum temperature reaches 39 ° C in summer and it drops to 11 °C below zero in winter. On average, the numbers of frost days per year are 100 days. Table 2 summarizes the climatic conditions in Mashhad.

Table2: climatic conditions in Mashhad, Iran

Parameters	Annual mean
Temperature (°C)	14
Sun Light Hours (h/month)	236.26
Evaporation (mm/month)	146.875
Wind Speed (m/s)	11.91
Precipitation(mm)	241
Absolute humidity (%)	53.5

Determination of Parameters

Samples were analyzed for Biochemical oxygen demand (BOD5), Chemical oxygen demand (COD), Total suspended solids (TSS), Dissolved oxygen (DO), Calcium (Ca), Magnesium (Mg), Sodium (Na), Boron (B), Temperature, and pH. Sodium adsorption rate (SAR) is also calculated by below formula:

$$\mathbf{SAR = Na / \sqrt{((Ca+Mg)/2)}}$$

Based on IDE new proposal for stabilization pond systems a 0.45μ filter was used to remove algal cells from TSS samples, because a major part of initial measured TSS was due to algal presence that occurs at high levels in the ponds. So, the reported amounts for TSS in this study are drawn from filtered samples. Ambient temperature in different seasons was also recorded to see its effect on removal efficiency variations.

Data Analyses

Statistical analyses were performed using SPSS. One way analysis of variance (ANOVA) and one sample t- test at a significant level of 0.05 was performed. Consequences compared with IDE standards. Simple linear regression analysis was used only for modeling. Drawing graphs were performed by Excel 2007 software.

RESULTS

Overall Assessment

Table 3 summarizes the annual average values both in the influent and final effluent and the mean removal efficiencies of some quality parameters in the OWTP during the investigated periods. Average removal efficiency for BOD5, COD, and TSS was 81, 83, and 78% respectively. With respect to the values displayed in table 3 for BOD_5, COD, and TSS the raw wastewater could be classified as medium to strong, in terms of them.

Table 3: the annual average values and removal efficiencies of quality parameters

period	TSS(mg/l)		%	BOD_5(mg/l)		%	COD(mg/l)		%
	In	Out		In	Out		In	Out	
2011-2012	378	86	77.1	371	75	79.7	831	145	82.5
2012-2013	507	109	78.4	479	83	82.7	851	146	82.8

A comparison between the monthly mean amounts of parameters in effluent and the standard concentrations of them is demonstrated in figures 2 and 3.

One way ANOVAs and One Sample t-test statistical analysis was performed for TSS, COD, and BOD5 description. Results of One way ANOVAs introduced a significant relationship between the seasons and the removal efficiency just in the first year of study not the second. One Sample t-test showed a significant correlation between the measured parameters and the defined effluent standards in both years (TSS, cod, and BOD5 = P value< 0.001) with an exception for TSS (P value = 0.052) in the second year. The amount of DO was always in a good condition and it didn't fall down the standard limit 2 mg/l. Average pH in raw wastewater in the first and second year was 7.82± 0.2 , 7.76 ± 0.05 respectively. Treatment performance didn't show any statistically significant relationship with inputting pH. The output value of pH was always within the determined standard levels (6-8.5). There was a direct and significant correlation between BOD5 and COD removal efficiency with temperature fluctuations (P<0.001). Regression analysis revealed that for one degree increasing in temperature, BOD5 and COD removal efficiencies rose up to the extent of 0.695 and 0.295 resp.

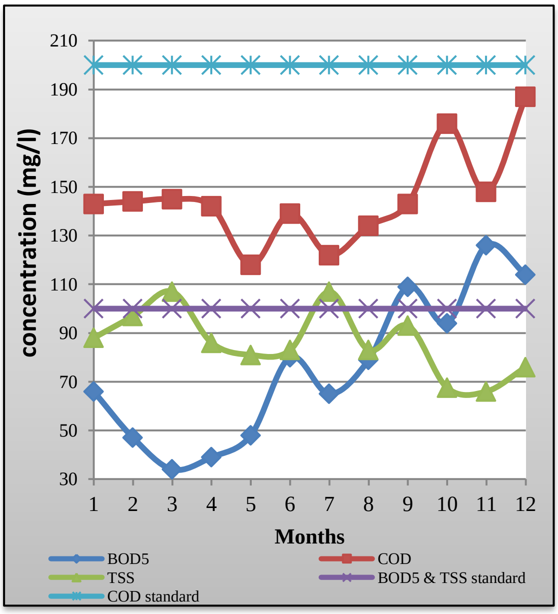

Fig.2: Monthly mean values in effluent at first year and their comparison with IDE agricultural and irrigation standards

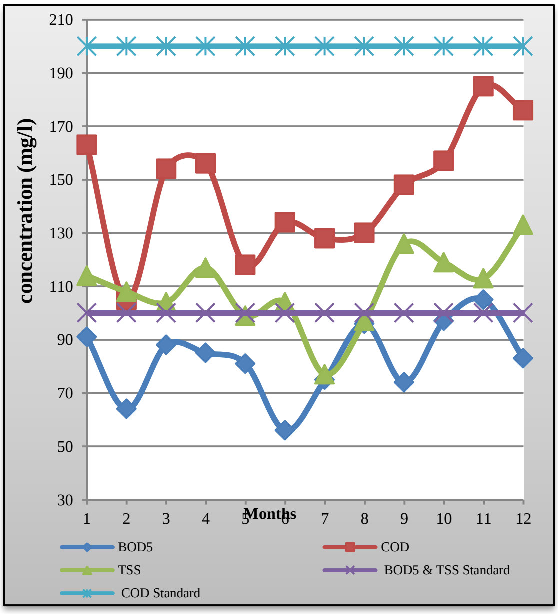

Fig.3: Monthly mean values in effluent at second year and their comparison with IDE agricultural and irrigation standards

Seasonal Variations of Parameters

In the first year: in raw sewage the maximum value for BOD5 and TSS observed in summer and was 550 and 420 mg/l respectively. COD maximum was 1193mg/l in mid spring. Lowest percentage of TSS removal obtained in spring 70% and the most removal occurred in mid winter 83%. On average, the maximum BOD5 reduction was seen in the summer and in mid winter it fell to its minimum 58%. The best result for COD received in the spring and in its middle it reached to 88% but it dropped to 74% in late winter. Outlet DO range was 2.02- 4.49 mg/l in which the highest amount is attributed to early spring and lowest measured in midsummer. In most cold months and late spring final pH showed growth in comparison with entrance pH, but it didn't exceed the limits. In the second year: Raw sewage highest values for BOD5, and COD showed 650 and 1169 mg/l respectively both in early autumn, and TSS most value was 813 mg/l in early spring. Removal efficiency variations range for parameters were as follows: BOD5= 71-88%, COD = 78-89%, TSS = 72-86%. The removal performance for all three BOD5, COD, and TSS was higher in spring compared to the other seasons and was lowest in winter. Variations in DO were not considerable and on average it calculated 2.88mg/l. outlet pH increased in whole spring and winter, but it was kept in the determined range. Temperature Seasonal changes of OWTP in both years are presented in figure4. As expected the most and least level of temperature observed in summer and winter respectively. The authentic quality standards and guidelines specified an optimum temperature range for the water used in irrigation 16-30℃. All the measured temperatures were right on this range.

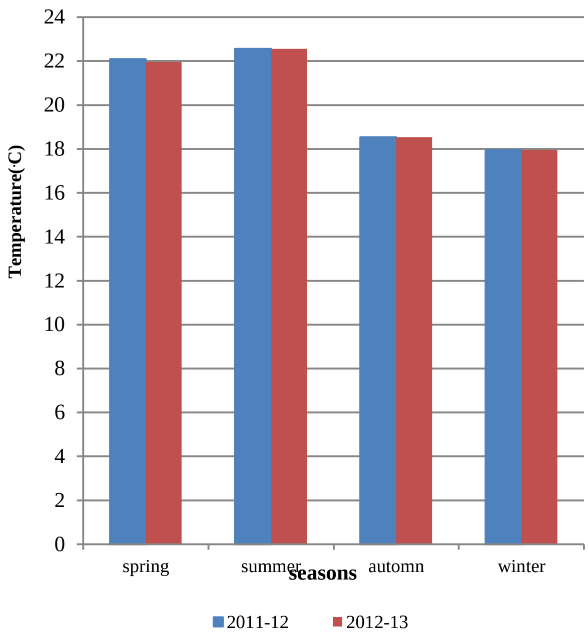

Fig.4: Average seasonal changes in effluent temperature

Table 4 has placed to show average seasonal amounts of Na, Ca, Mg, and B in effluent. There are severe limitations on using effluent as irrigation if its Na content goes higher 0.9 meq/l. The most permissible amount for B in irrigation water is 1mg/l. So OWTP effluent didn't show any problem in this regard. Ca and Mg are necessary for calculating SAR. SAR is used for evaluating the toxicity caused by Na ion. Figure 5 presents average seasonal values for SAR. Based on existing standard for SAR, its value below 10 is acceptable in irrigation usages.

Table 4: seasonal mean of Na, Ca, Mg, and B in effluent

Season	spring				summer				autumn				winter			
parameter	Na (meq/l)	Ca (mg/l)	Mg (mg/l)	B (mg/l)	Na (meq/l)	Ca (mg/l)	Mg (mg/l)	B (mg/l)	Na (meq/l)	Ca (mg/l)	Mg (mg/l)	B (mg/l)	Na (meq/l)	Ca (mg/l)	Mg (mg/l)	B (mg/l)
2011-12	12.2	76	40	0.2	12.8	66.66	48	0.6	10.7	55.33	47	0.6	9.3	75.33	35.66	0.8
2012-13	11	89.3	28	0.1	8.85	98.6	18	0.2	7.3	91.3	16.33	0.3	7.2	77	10.33	0.9

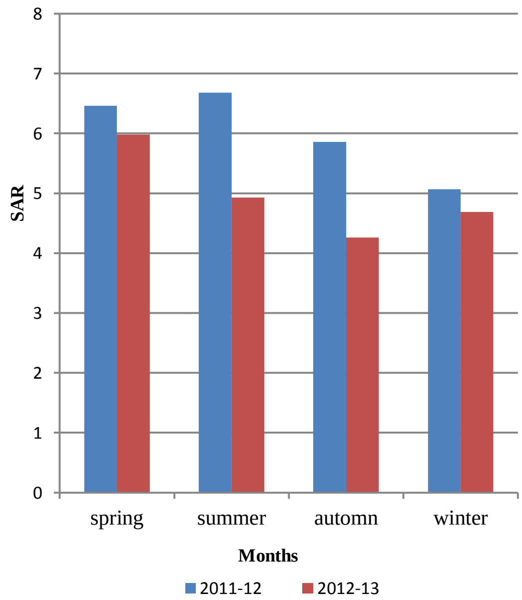

Fig.5: Average seasonal values of SAR

DISCUSSION

The range of BOD5/COD at entrance calculated 0.5 and it declared 0.3-0.8 in municipal raw wastewaters. If this ratio goes higher than 0.5 in raw wastewater, it can easily be treated by biological processes. In terms of pollution, OWTP untreated wastewater can be classified relatively severe. According to various texts ponds can treat 70 - 80% of BOD5 of input samples that are not filtered, and to 90% of filtered samples. BOD5 removal efficiency declined to below 60% in the early to mid winter of the first year. It can be justified by temperature falling and sunny hour's reduction in the January and February months. In the Bojcevska *et al*. study on the sugar factory stabilization pond treatment plant in West Kenya, the results showed that seasonal variations have a significant impact on the removal of TSS load in raw wastewater [18]. High TSS level that occurs in the stabilization pond effluent, is primarily due to high concentrations of algal cells. However, it must be considered that this algal presence can cause a significant increase in agriculture efficiency as a plant fertilizer and soil amendment [19]. According to Figure 2 and 3, TSS output standards are better meet at first year not the second; given that there was not implemented changes in the plant, this difference in TSS removal efficiency can be explained by the in putting volume variations to plant. As it was mentioned previously in the result section, there was a growth in both TSS and DO in early spring in the first year. We can attribute this event to algal bloom that produces oxygen and appear as TSS in effluent. Farzadkia in his study on the application of stabilization ponds for slaughterhouse wastewater treatment of Kermanshah city found a meaningful difference between the mean concentrations of TSS, BOD, and COD in effluent and IDE Standards for effluent disposal into surface waters and agricultural lands. However, it must be considered that pollutants concentration in the effluent exceeded the standard amounts because of the extremely high rates of in putting pollution [20].Unlike the previous study BOD5, COD, and TSS values in the effluent of Egyptian Sadat city stabilization pond were 49,135, and 61 mg/l, but these little quantities can be due to the low concentration of incoming pollutants to the plant [21]. Temperature is part of the most important physical parameters in evaluating the irrigation water. Plant growth and its germination, blockage in irrigation systems and also soil pore block is influenced by temperature variations. Obtained values for OWTP demonstrate an acceptable effluent temperature in all seasons. When using wastewater for irrigation its mineral and organic compounds must be considered due to their influence on plant growth, structure and chemical properties of soil. Agricultural land application of OWTP effluent regarding Na content has severe limitations because of its high potential for soil structure destruction. Based on Ayers & vestcot this plant effluent application concerned with SAR is associated with low to moderate restrictions [22]. Ayers & vestcot in their quality guideline stated that there is no restriction on using water with a B concentration less than 0.7 mg/l. Hence quality effluent in terms of B concentration for irrigation of agricultural products is assessed suitable with an exception in winter.

CONCLUSION

According to the survey results variations of quality parameters were not affected by inputting pH, but they were dependant on ambient temperature changes. Obtained results indicated that the effluent of OWTP was complied with IDE standards for agricultural reuse in terms of BOD5, and COD. Based on SAR and B results there is not a concern for using the effluent on agricultural purposes, but there was an alarming level of sodium. Totally, OWTP performance can be characterized satisfactory. At the end, it could be said that municipal wastewater treatment plant effluent can be an essential source and desirable alternative in order to meet the water needs of the agricultural sector if they are operating properly.

ACKNOWLEDGEMENT

We are all highly appreciated for the assistance of Mashhad Water and Wastewater Company.

ETHICAL ISSUES

Ethical issues (including plagiarism, informed consent, misconduct, data fabrication and/or falsification, etc.) have been completely observed by the authors.

COMTETING INTERESTS

The authors have stated that no competing interest exists.

AUTHORS' CONTRIBUTIONS

Rahmatiyar and Alipour conceived and designed the study. Rahmanpour performed the literature search and wrote the manuscript. All authors contributed to the data acquisition, analysis and interpretation.

REFERENCES

[1] Ehrampoush M, Hosseinshahi D, Ebrahimi A, Ghaneian M, Lotfi M, Ghelmani S, *et al.* Evaluation of the Efficiency of Sub-Surface Constructed Wetland Methods in Wastewater Treatment in Yazd City in 2011. Tolooebehdasht. 2013;12(1):33-43 [Persian].

[2] Ensink JH, Mukhtar M, van der Hoek W, Konradsen F. Simple intervention to reduce mosquito breeding in waste stabilisation ponds. Transactions of the Royal Society of Tropical Medicine and Hygiene. 2007;101(11):1143-46.

[3] Al-Hashimi MAI, Hussain HT. Stabilization pond for wastewater treatment. J Euro Sci. 2013;9(14): 278-94.

[4] Mburu N, Tebitendwa SM, van Bruggen JJA, Rousseau DPL, Lens PNL. Performance comparison and economics analysis of waste stabilization ponds and horizontal subsurface flow constructed wetlands treating domestic wastewater: A case study of the Juja sewage treatment works. J of Environmental Management. 2013;128:220-25.

[5] Yi Q, Kim Y, Tateda M. Evaluation of nitrogen reduction in water hyacinth ponds integrated with waste stabilization ponds. J Desalination. 2009;249(2):528-34.

[6] Kaya D, Dilek FB, Gökçay CF. Reuse of lagoon effluents in agriculture by post-treatment in a step feed dual treatment process. J Desalination. 2007;215(1–3):29-36.

[7] Symonds EM, Verbyla ME, Lukasik JO, Kafle RC, Breitbart M, Mihelcic JR. A case study of enteric virus removal and insights into the associated risk of water reuse for two wastewater treatment pond systems in Bolivia. J Water Research. 2014;65:257-70.

[8] Reinoso R, Torres LA, Bécares E. Efficiency of natural systems for removal of bacteria and pathogenic parasites from wastewater. J Sci of The Total Environment. 2008;395(2–3):80-6.

[9] Almasi A, Dargahi A, Pirsaheb M. The Effect of Different Concentrations of Phenol on Anaerobic Stabilization Pond Performance in Treating Petroleum Refinery Wastewater. J Water and Wastewater. 2013;24(85):61-8[Persian].

[10] Toumi A, Nejmeddine A, El Hamouri B. Heavy metal removal in waste stabilisation ponds and high rate ponds. J Water Science & Technology. 2000;42(10):17-21.

[11] Gray N. Biology of wastewater treatment. 2th ed. Imperial College Press, London; 2004.

[12] Short MD, Cromar NJ, Fallowfield HJ. Hydrodynamic performance of pilot-scale duckweed, algal-based, rock filter and attached-growth media reactors used for waste stabilisation pond research. J Ecological Engineering. 2010;36(12):1700-708.

[13] Del Nery V, Damianovic MHZ, Pozzi E, de Nardi IR, Caldas VEA, Pires EC. Long-term performance and operational strategies of a poultry slaughterhouse waste stabilization pond system in a tropical climate. J Resources, Conservation and Recycling. 2013;71:7-14.

[14] Tadesse I, Green FB, Puhakka JA. Seasonal and diurnal variations of temperature, pH and dissolved oxygen in advanced integrated wastewater pond system® treating tannery effluent. J Water Research. 2004;38(3):645-54.

[15] Pirsaheb M, Sharafi K, Dogaohar K. Comparison of Mashhad olang wastewater treatment plant effluent with wells water quality for irrigation. J Water and Wastewater. 2013;23(84):116-21 [Persian].

[16] Almasi A, Pirsaheb M, Dargahi A. The efficiency of anaerobic wastewater stabilization pond in removing phenol from Kermanshah Oil Refinery Wastewater. Iranian Journal of Health and Environment. 2012;5(1):41-50 [Persian].

[17] Muga HE, Mihelcic JR, Reents NW, Morales S, Gemio G, Ballard M, *et al.* Treatment Performance of Wastewater Lagoons in South Yungas Province of Bolivia. Procedings of the World Environmental and Water Resource Congress; May; ASCE Kansas City, MO 2009.
[18] Bojcevska H, Tonderski K. Impact of loads, season, and plant species on the performance of a tropical constructed wetland polishing effluent from sugar factory stabilization ponds. J Ecological Engineering. 2007;29(1):66-76.
[19] Mazhab S, Falahzade M, Ghaneeian M, Rahmani SJ. Effects of Organic Load, pH, and EC Variations of Raw Wastewater and Weather Condition on the Efficiency of Yazd Stabilization Ponds. J Water and Wastewater. 2009;20(70):55-61[Persian].
[20] Farzadkia M. Application of High Rate Stabilization Ponds for Treatment of Kermanshah City Slaughterhouse. J Water and Wastewater. 2004;15(51):10-5[Persian].
[21] Nasr F, EL-Ashmawy A, Eltaweel G, EL-Shafai S. Waste stabilization ponds for wastewater treatment and reuse in Egypt. 1 st International Conference in Hazardous Waste Management;Oct; Khania 2008. Available from: http://www. Researchgate.net
[22] Ayers RS, Westcot DW. Water quality for agriculture: Food and Agriculture Organization of the United Nations Rome; 1985. Available from: http://www .fao.org /DOCReP /003 /T0234e /T0 23 4e 00.htm