EFFECT OF THE RETENTION TIME AND THE PHENOL CONCENTRATION ON THE STABILIZATION POND EFFICIENCY IN THE TREATMENT OF OIL REFINERY WASTEWATER

Ali Almasi[1], Abdollah Dargahi[1], Abdeltif Amrane[2], Mehdi Fazlzadeh[3,]*, Mojtaba Mahmoudi[1] and Amirhossein Hashemian[1]

[1]Department of Environmental Health Engineering, School of Public Health, Kermanshah University of Medical Sciences, Kermanshah, Iran
[2]Ecole Nationale Supérieure de Chimie de Rennes, Université de Rennes 1, CNRS, UMR 6226, Rennes, Avenue du Général Leclerc, CS 50837, 35708 Rennes Cedex 7, France.
[3]Department of Environmental Health Engineering, School of Public Health, Ardabil University of Medical Sciences, Ardabil, Iran

ABSTRACT

Phenols are among the most common organic pollutants because of their toxicity even at low concentrations. The effects of the retention time and the phenol concentration on the stabilization pond efficiency in the treatment of oil refinery wastewater were the purpose of this study, and hence the input of a pilot unit was varied in terms of phenol concentrations and retention time. The following parameters have been examined, NH_4^+, PO_4^{3-}, phenol, TCOD, SCOD, TBOD, SBOD and pH. The results showed that the average efficiency in the stabilization ponds varied in the ranges 71.9 – 91.2%, 76.4 – 93.3%, 68.4 – 91.7%, 75.9 – 93.7% and 77.6 – 98.0% for the removal of SCOD, TCOD, SBOD, TBOD and phenol, respectively. These results indicated that the phenol concentration and the retention time affected dramatically the anaerobic and facultative ponds performance, so that the system performance was significantly increased by decreasing the phenol concentration and increasing the retention time. It can be concluded that stabilization ponds show favorable performance in removing organic compounds at various phenol concentrations and high retention times; this system can be therefore used to replace rather expensive and complex systems such as active sludge.

KEYWORDS: anaerobic and facultative stabilization pond, phenol removal, oil refinery wastewater, retention time

1. INTRODUCTION

Phenol (C_6H_5OH) is a toxic aromatic hydrocarbon. Solid phenol is white but is mostly colored due to the presence of impurities [1]. At room temperature, phenol is a translucent, colorless, crystalline, white powder or syrupy liquid on mixing with water. Phenol has a sweet tar like odor and is soluble in alcohol, glycerol, petroleum and also but to a lesser extent in water [2]. Phenol and its derivatives are among the most common organic pollutants because of their toxicity even at low concentrations [1, 3]; they can be found in wastewater of many chemical plants such as paper and pulp, pesticides, dyes, and chemical manufacturing industries. Besides, wastewater originating from other industries such as resin manufacturing, gas and coke manufacturing, tanning, textile, plastic, rubber, pharmaceutical, oil refineries, ceramic, steel, coal conversion processes, phenolic resin industries and petroleum also contains various types of phenols [3-5]. Phenols are also present in domestic effluents and vegetation decay [5]. Therefore, wastewaters containing phenolic compounds present a serious discharge problem due to their poor biodegradability, high toxicity and ecological aspects [3].

Phenol shows also significant health effects for humans. The manufacture and transportation of phenol as well as its many uses may lead workers to a high exposure to this substance through inhalation, ingestion, eye or skin contact, and absorption through the skin. Phenol is rapidly absorbed through the skin and can cause skin and eye burns upon contact. Comas, convulsions, protein degeneration, tissue erosion, paralysis of the central nervous system, cyanosis and death can result from an overexposure. Internally, phenol affects the liver, kidneys, lungs, and vascular system. The ingestion of 1 g of phenol is deadly for human [1, 6]. Therefore, they are considered as priority pollutants since they are harmful to organisms even at low concentrations and many of them have been classified as hazardous pollutants because of their potential harm to human health [6]. According to the World Health Organization regulation, 0.002 mg/l is the permissible limit for phenol concentration in potable water and the regulation by the Environmental Protection Agency (EPA), call for lowering phenol content in wastewater less than 1 mg/l [3]. Consequently, wastewater containing phenols and other toxic compounds must be treated before discharge into the aquatic

* Corresponding author

environment to avoid legal problems [7]. Biological processes, physical–chemical processes, adsorption processes, solvent extraction, chemical oxidation, membrane processes, reverse osmosis, ion exchange and electrochemical methods are the most widely used methods for removing phenol and phenolic compounds from wastewater [1, 3]. Some problems, such as high cost, low efficiency, formation of toxic by-products and applicability to a limited con-centration range are associated with the above methods. Contrarily, biological methods have little or no harmful effects on the environment, because these techniques do not involve the use of harmful reagents [8].

Among the natural biological treatment systems available, stabilization ponds are one of the simplest natural biological processes [9]. Waste stabilization ponds or lagoons offer the simplest solution for the treatment of industrial and municipal wastewaters and are widely used in developing countries especially in rural areas [10]. Stabilization ponds provide a cheap and attractive alternative to conventional processes, in case adequate land is available [11]. Nowadays, many wastewater stabilization ponds are efficiently used in different countries such as Ghana, Egypt, Portugal, Iran, Mexican, England, Nigeria and other countries for domestic and industrial wastewater treatment [12-15]. Wastewater stabilization ponds have been used as a series of anaerobic and facultative maturation ponds in most parts of the world. In these systems, pollutants are removed from streams through settling operation or biological and chemical convert processes [10, 16]. Anaerobic ponds are the smallest units in the series. They are sized according to their volumetric organic loading, which are in the range of 100 to 350 g BOD_5/m^3 day, depending on the design temperature [17].The depth of anaerobic ponds is in the range 2−5 m and the Hydraulic Retention Time is usually between 2 and 5 days [17]. Anaerobic ponds work extremely well in warm climates: for example, a properly designed pond will achieve around 60 percent BOD_5 removal at 20°C and over 70 percent at 25°C and above [11-13, 17].

Literature survey shows that there is no comprehensive research on phenol removal from oil refinery wastewater by anaerobic stabilization pond system. Therefore, the main purpose of the present study was to build an anaerobic pond at pilot scale and operating in continuous flow to understand the effect of retention time and phenol concentration on the anaerobic pond efficiency in the treatment of Kermanshah oil refinery wastewater.

2. MATERIALS AND METHODS

This study was undertaken using a laboratory scale stabilization pond consisting of anaerobic (0.2×1×1m) and facultative (0.2×1×1m) ponds of 400 L capacity and made of 6 mm fiberglass plate. The temperature of the ambient air was in the range of 25 to 42°C. The average temperature of ponds was kept to 21±2ºC. The considered hydraulic retention times of the anaerobic pond were 2 and 5 days and hydraulic loads of this system were 40 and 95 L/day. The hydraulic retention times of the facultative pond were 5 and 10 days, while the surface overflow of this pond was varied according to Table 1. Inlet of stabili-

TABLE 1 - The surface overflow rates of the facultative pond according to the retention time and for various phenol concentrations

Parameter	Retention time (day)	Phenol concentration (mg/l)					
		0-28	30-70	90-130	150-200	100-140	200-260
surface overflow (kgBOD/ha.day)	5	66.97	89.97	37.89	51.83	63.11	80.58
	10	67.44	99.46	123	185.88	70.64	74.61

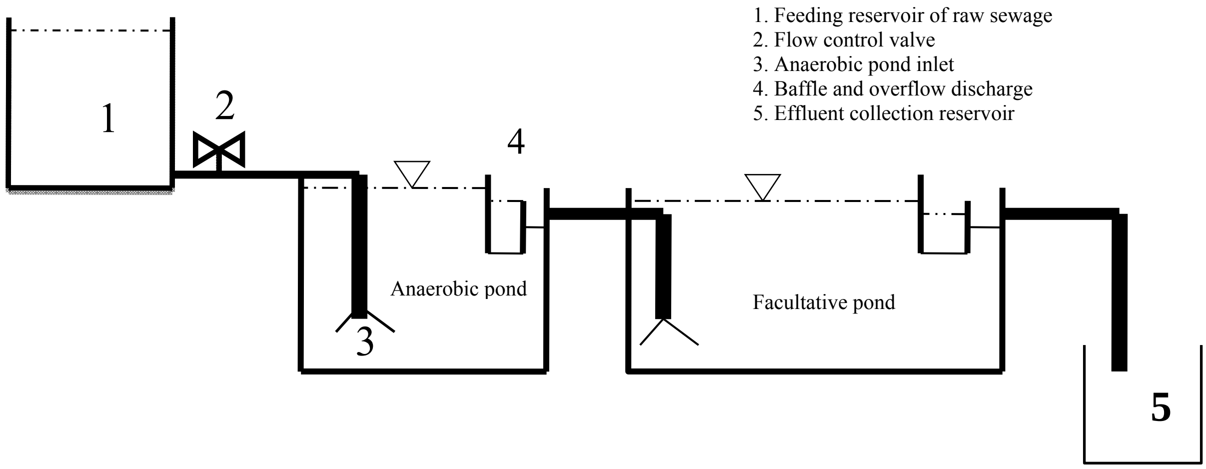

FIGURE 1 - Schematic diagram of the system: anaerobic and facultative stabilization pond pilots

zation pond was placed 30 cm under the level of ponds' liquid. Full characteristics of the pilot ponds used are shown in Figure 1. The pond was daily loaded by the wastewater output of oil and grease separator unit of Kermanshah Oil Refinery. Results of initial tests to determine the quality of this wastewater are given in Table 2. For seeding and inoculation before the launch of the system, it was loaded with wastewater; 1.5 liters of sewage sludge and one liter of previously prepared sludge from the oil refinery plant was added to the system input after mixing and homogenization. After 3 months of seeding, the stabilization pond system was ready for launching. To adjust the stabilization pond loading within the defined ranges, in addition to increasing the amount of phenol, molasses was used so that the pond loading was adjusted to reach the specified amount for each stage simultaneous with the increase in the amount of phenol and molasses. To provide the required light for the facultative pond used, a 690 lux fluorescent lamps were used which were turned on during 12 hours per day, and the required aeration was supplied by an electric blower. Phenol was added to the input of the pilot at various concentrations (100, 200, 300, and 400 mg/L), while both high (above 20ºC) and cold (lower than 10ºC) temperatures were considered. On each sample, NH_4^+, PO_4^{3-} and phenol were measured by means of a Varian spectrophotometer UV-120-20 model at 425, 690 and 500 nm wavelengths, respectively. TCOD, SCOD, TBOD, SBOD and pH were also measured on each sample according to standard methods for the examination of water and wastewater [18].

TABLE 2 - Determined parameters of the output raw wastewater from the Kermanshah Oil Refinery

Parameter	Amount
TCOD	622 mg/l
SCOD	495 mg/l
TBOD	204 mg/l
SBOD	126 mg/l
TSS	56 mg/l
VSS	44 mg/l
N-NH3	13.1 mg/l
Phenol	69.6 mg/l
pH	7.9

Oxidation and reduction potential of pond were monitored to maintain and provide anaerobic conditions. This parameter was determined using a Kent ORP meter (7020 model with the Eil sensors). The phenol used was of analytical grade and was obtained from Merck (Germany). To check for possible phenol volatility, the pond's surface was isolated with a layer of paraffin and plastic cover and the system performance was then evaluated. Five consecutive samples showed that the performance rate of the anaerobic pond was almost the same in both open and closed conditions. After selected parameters were examined, the removal percentage (R %) of pollutants was calculated for each run by using Eq. (1):

$$R\% = \left[\frac{Ci - Ce}{Ci}\right] \times 100 \quad (1)$$

Where C_i and C_e were the initial and final concentrations of pollutants in the solution, respectively.

In this study, in total 5040 samples were measured for two retention times and 4 phenol concentrations. Descriptive statistics were used for presenting data and analytical statistics (e.g. t-test, and ANOVA) were applied for comparison of the efficiency of the anaerobic stabilization pond for phenol removal for the various concentrations tested using SPSS ver.12 software. All sampling procedures and parameters analysis were done according to standard methods for the examination of water and wastewater [18]. Operating conditions of the anaerobic pond system are based on Almasi and Pescod experiments [19].

3. RESULTS AND DISCUSSION

Qualitative results of tests done on influents and effluents of anaerobic and facultative stabilization ponds are listed in Tables 3-6 and Figures 2 and 3. Tables 3 and 4 show the wastewater characteristics of influent and effluent of anaerobic and facultative stabilization ponds for different retention times and different phenol concentrations. Average removal efficiencies of the measured parameters for various phenol concentrations and various retention times of effluent from anaerobic and facultative stabilization ponds of Kermanshah oil refinery are displayed in Tables 5 and 6.

It should be mentioned that during the study, pH values in influent of stabilization pond, effluent of anaerobic pond, and effluent of facultative pond were in the ranges 7.5-8, 6.5-7.5, and 7.5-8.5 respectively. The dissolved oxygen amount in the facultative pond was about 2-4 mg/l which led to excessive breeding of insects larva especially mosquitoes at the pond surface. The only alga in the facultative pond was *Phormidium* which is able to grow at high sulfur concentrations. It can be observed that the smell of oil which was detected in the raw wastewater and the anaerobic pond was removed in the effluent system. Furthermore, the average ORP value of the anaerobic pond (ORP <- 246) proved the anaerobic conditions for the four different concentrations of phenol at the two retention times, 2 and 5 days, in the anaerobic pond.

Statistical analysis of the data was indicative of the fact that the independent parameters (phenol concentration and retention time) have dramatically affected the anaerobic and facultative ponds performance in oil refinery wastewater treatment, so that the system performance was significantly increased by decreasing the phenol concentration and increasing the retention time ($P<0.001$). The results showed that the average efficiency in the stabilization ponds for the removal of SCOD, TCOD, SBOD, TBOD and phenol were the highest for 5 days retention time in the anaerobic pond, 10 days in the facultative pond and 100 mg/L phenol concentration leading to 91.2, 93.3, 91.7, 93.7, 98.0% removal, and the lowest for

2 days retention time in the anaerobic pond, 5 days in the facultative pond and 400 mg/L phenol concentration, leading to71.9, 76.4, 68.4, 75.9, 77.6% removal, respectively (Figures 2 and 3, Table 5 and 6).

TABLE 3 - Wastewater characteristics of the influent and the effluent of the anaerobic and the facultative stabilization ponds for various phenol amounts and retention times of 2 and 5 days for anaerobic and facultative ponds

(mg/l) phenol	PO_4 (mg/l)	NH_3 (mg/l)	COD (mg/l)		BOD5 (mg/l)		influent concentrations of phenol (mg /l)	Parameter
			SCOD	TCOD	SBOD	TBOD		
170.22±20.81	1.72±0.82	13.7±5.16	510.95±78.65	651.007±79.85	131.24±26.73	210.63±31.26	100	influent
261.71±12.41	2.22±0.61	18.61±2.87	639.25±63.78	773.72±55.88	178.56.26.27	249.59±21.86	200	
363.8±16.85	2.54±0.34	17.38±3.76	703.35±98.65	857.35±98.65	198.86±31.91	277.36±31.91	300	
464.18±17.99	2.62±0.39	18.38±3.76	804.2±84.88	966.1±84.88	218.65±17.66	302.06±17.66	400	
17.34±8.78	0.61±0.33	5.69±3.03	136.17±73.36	162.76±91.72	40.8±16.04	59.83±20.31	100	Effluent of anaerobic pond
76.9±13.37	0.9±0.26	10.6±2.6	214.59±45.06	239.59±43.77	60.64±13.58	81.84±15.67	200	
132.63±16.75	1.36±0.24	10.54±2.22	301.62±54.41	319.36±55.79	79.45±17.22	105.74±13.4	300	
205.15±25.4	1.52±0.27	12.25±2.24	407.08±56.41	429.24±57.26	110.51±22.84	140.82±22.84	400	
9.11±4.63	0.53±0.28	1.98±0.91	69.74±37.79	79.83±44.91	23.06±8.95	28.86±9.89	100	Effluent of facultative pond
62.29±16.74	0.76±0.23	3.07±0.82	108.08±24.39	111.88±30.06	39.05±9.83	38.52±8.03	200	
104.09±16.74	1.11±0.24	7.19±2.22	161.65±54.4	168.22±55.95	35.02±17.22	54.87±13.4	300	
104.09±25.42	1.23±0.27	8.95±2.2	226.55±56.41	227.52±57.27	68.97±21.72	72.82±2.84	400	

TABLE 4 - Wastewater characteristics of the influent and the effluent of the anaerobic and the facultative stabilization ponds for various phenol amounts and 5 and days retention times in the anaerobic and the facultative ponds

Phenol(mg/l)	PO4 (mg/l)	NH3 (mg/l)	COD (mg/l)		BOD5 (mg/l)		influent concentrations of phenol (mg /l)	Parameter
			SCOD	TCOD	SBOD	TBOD		
171.71±12.39	2.46±0.47	16.38±2.18	1435.46±199.66	1586.06±199.66	418.67±34.8	500.07±34.81	100	influent
266.44±9.65	2.64±0.46	20.7±3.01	1608.49±69.18	1873.49±69.18	494.88±20.21	418.67±34.8	200	
369.38±14.3	2.74±0.4	20.19±4.4	1780.35±63.26	2061.85±63.26	513.74±20.21	658.74±20.21	300	
464.42±15.44	2.78±0.41	19.33±3.83	2171.2±245.73	2378.56±255.26	630.6±65.61	717.36±65.61	400	
11.01±1.8	0.73±0.17	6.39±1.06	303.62±56.82	316.32±69.42	96.92±10.69	106.48±16.98	100	Effluent of anaerobic pond
48.9±13.37	0.9±.025	9.04±2.01	424.88±43.74	440.38±43.74	138.94±15.67	157.84±15.67	200	
113.05±11.17	1.27±0.21	10.08±2.24	554.3±15.41	567.3±15.41	170.4±15.42	194.3±15.43	300	
180.5±10.5	1.38±0.2	11.45±2.14	897.14±119.97	900.67±124.8	271.6±33.72	293.5±33.72	400	
3.45±1.53	0.66±0.16	1.94±1.05	125.5±46.92	106.06±55.95	34.81±11.43	31.66±10.99	100	Effluent of facultative pond
14.44±7.6	0.78±0.26	2.81±1.52	159.88±48.73	159.74±48.95	44.76±17.46	39.84±5.30	200	
36.05±11.17	1.21±0.21	4.08±2.04	215.3±15.41	205.3±10.23	58.4±15.41	57.40±13.72	300	
91.5±10.5	1.26±0.2	5.18±1.4	450.14±119.97	478.67±123.76	120.6±53.13	129.5±33.72	400	

TABLE 5 - Mean removal efficiency of the measured parameters in the effluent of the stabilization pond of Kermanshah oil refinery (retention times of 5 and 10 days for the anaerobic and the facultative ponds)

Parameter		phenol concentration of 100 mg/l		phenol concentration of 200 mg/l		phenol concentration of 300 mg/l		phenol concentration of 400 mg/l		P-value
		Anaerobic pond	facultative pond	Anaerobic pond	facultative pond	Anaerobic pond	facultative pond	Anaerobic pond	facultative pond	
BOD (%)	TBOD	78.7	70.26	73.32	74.76	70.52	70.45	59.13	55.87	<0.001
	SBOD	76.84	64.08	71.84	67.78	66.85	65.72	56.96	55.59	<0.001
COD (%)	TCOD	80.18	66.47	76.44	63.72	72.47	63.81	62.12	46.85	<0.001
	SCOD	78.89	58.66	73.51	62.37	68.84	61.15	58.67	49.82	<0.001
NH_3 (%)		61.08	69.64	56.22	68.91	49.12	59.52	40.21	54.76	<0.001
PO_4 (%)		70.09	9.59	65.19	13.33	53.16	4.72	49.73	8.69	<0.001
Phenol (%)		93.58	68.66	81.63	70.47	69.38	68.11	61.12	49.3	<0.001

TABLE 6 - Mean removal efficiency of the measured parameters in the effluent of the stabilization pond of Kermanshah oil refinery (retention times of 2 and 5 days for the anaerobic and the facultative ponds)

Parameter		phenol concentration of 100 mg/l		phenol concentration of 200 mg/l		phenol concentration of 300 mg/l		phenol concentration of 400 mg/l		P-value
		Anaerobic pond	facultative pond	Anaerobic pond	facultative pond	Anaerobic pond	facultative pond	Anaerobic pond	facultative pond	
BOD (%)	TBOD	71.75	51.76	67.02	52.93	61.69	48.11	53.5	48.28	<0.001
	SBOD	68.95	43.48	65.3	35.6	59.83	55.92	49.67	37.59	<0.001
COD (%)	TCOD	74.99	50.95	68.95	53.3	62.83	47.32	55.63	46.99	<0.001
	SCOD	73.34	48.78	66.26	49.63	57.14	46.4	49.41	44.35	<0.001
NH_3 (%)		59.91	69.95	43.39	71.03	39.03	38.78	32.54	26.93	<0.001
PO_4 (%)		64.34	13.11	58.23	15.55	46.41	18.38	41.15	19.07	<0.001
Phenol (%)		89.82	47.46	70.53	47.71	63.47	49.2	55.86	49.26	<0.001

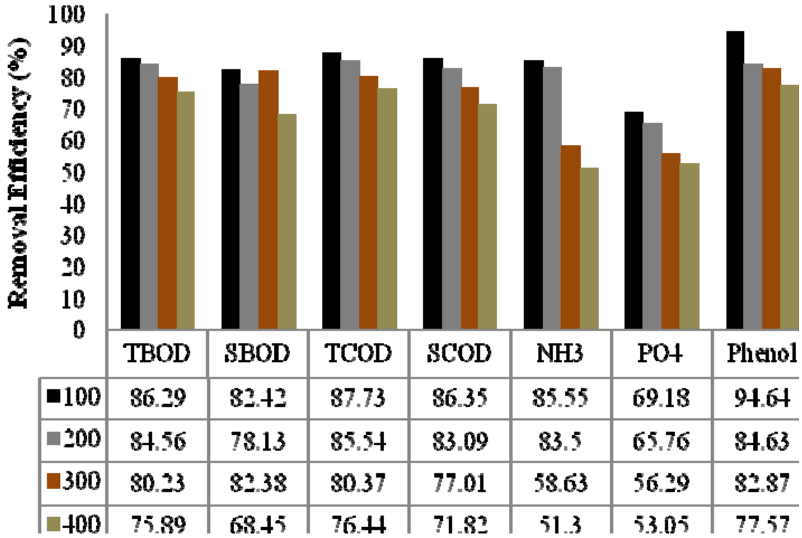

FIGURE 2 - Mean removal efficiency of the measured parameters for 5 days retention time and various phenol amounts in the stabilization pond treating the effluent from the Kermanshah oil refinery

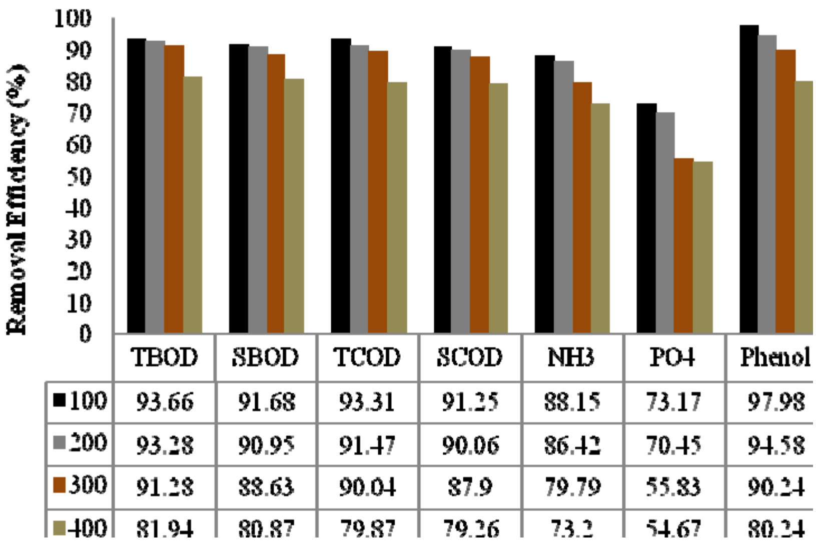

FIGURE 3 - Mean removal efficiency of measured parameters in different concentrations of phenol and retention time of 10 day in stabilization pond effluent of Kermanshah oil refinery

The results showed that the independent parameters have affected the stabilization ponds performance in oil refinery wastewater treatment. It seemed that the main reason of decreasing phenol removal from the stabilization pond for increasing phenol amounts was most likely due to toxic effects of phenol for algal species and phenol-degrading bacteria. Domestic wastewater and oil refinery wastewater were combined in this work, and consequently several kinds of algae were found in the facultative pond which was due to the reduction of sulfur content in the influent. The wastewater of oil refinery was then discharged to the facultative pond separately; hence and despite the perfect conditions for algal growth in the facultative pond, only *Phormidium* alga species was observed which was due to its resistance to high sulfur concentrations in the influent.

If compared to other findings, such as those of Mahassen and Azza [20], the anaerobic stabilization pond showed a higher efficiency, since COD, BOD_5 and PO_4^{3-} removal efficiency by the anaerobic and the facultative ponds were 28.9, 22.2, 16.9% and 48.9, 50.6, 47.8% respectively. According to these results, it can be inferred that biochemical reactions in the anaerobic pond can convert significant amount of recalcitrant COD, particularly cyclic hydrocarbons such as phenol, to biodegradable organic compounds. Indeed, in such process the possibility of increasing the BOD is provided. Therefore, the BOD values increased in the system and thus it seemed that the BOD removal efficiency in anaerobic ponds was low. In other words, removal of BOD in facultative and aerobic ponds was higher than in anaerobic ponds.

Moussavi et al. [21] proved that the removal efficiency of COD and Phenol by using biological methods was equal to 34.7 and 28.1%, respectively, which is similar to the proportion of COD removed in the facultative pond of the present study for a retention time of 5 days. Vazquez et al. [22] used aerobic biodegradation system for phenol removal and their results showed that the removal efficiency of COD, phenol and Ammonia-N were 75%, 98%, and 71%, respectively. Also, Uygur et al. [23] showed that increasing the phenol concentration, the performance of SBR system for COD, Ammonia-N and phenol removal decreased, so that the maximum removal yields of COD, Ammonia-N and phenol were 95%, 90% and 90 % respectively, which were observed at low phenol concentration, in agreement with the present results. Indeed, the highest removal yields for COD and phenol were 93.3% and 88.2% in the anaerobic pond and 73.2 and 98.0 % in the facultative pond for 5 and 10 days retention time respectively and 100 mg/l initial phenol amount. Naddafi et al. investigated on the performance of aerated lagoons for industrial wastewater treatment and showed that the removal of BOD_5 and COD was equal to 73.5% and 89.95 %, respectively [24]. Mohammadyari and Balador (2008) studied the efficiency of mobiling bed biofilm reactor for the treatment of combined industrial and municipal wastewater at various retention times and several pollution loads [25]. About 76 % of COD was removed in the worst conditions and the high efficiency of the system for COD removal was attributed to the combination of industrial and municipal wastewater which limited adverse shocks to the treatment system [25]. Abdelwahab et al. [26] obtained 94.5 % of phenol removal from oil refinery wastewater by using an electrocoagulation method. Moussavi et al. [27] proved that application of moving-bed sequential continuous-inflow reactor (MSCR) can remove 99% and 96 % of phenol and COD, respectively. Khan et al. [28] showed that the removal rate of COD and phenol by using aerobic granular technology was equal to 94% and 95 % respectively, which appeared similar to the results of the present study at low phenol concentration. Gheisari et al. [29] obtained 35% and 61% COD and BOD_5 removal in anaerobic lagoon and activated sludge process section during the treatment of wastewater from the dairy industry, and the total removal for the whole system was approximately 96 %. Although the total removal was greater than the facultative pond of the present study, it was nearly similar to the global efficiency of the whole system considered in this study. In recent years, research on various methods of biological treatment including biodegradation of oil refinery effluents in a rotating biological contactor (RBC) pilot was performed. Results indicated that the TCOD removal efficiency by this system was 99% [30]. Moussavi et al. [31] used an aerobic granular sludge batch reactor system (AGSBR) for the removal of phenol from wastewater and showed more than 99 % removal of phenol and COD. It was also shown that emulsion liquid membrane system (ELM) can remove 97 % of phenol from wastewater [32].

Alemzadeh et al. [33] showed that phenol removal efficiency from oil refinery effluent using a laboratory-scale RBC system was 99.9%. Rahmani’s et al. study [34] showed that the highest efficiency of phenol removal (50 mg/l initial concentration) was obtained using the UV/TiO_2 process (80%); however, this technology used is expensive and requires some technical proficiency; contrarily to the technology used in this study, which is the simplest and the most flexible environmental technology. Using a laboratory-scale facultative stabilization pond to treat high phenol content wastewaters, the highest and lowest removal rates were related to 1000 (92%) and 4000 (22%) mg/l concentrations, respectively [35], but no independent result was found regarding phenol removal in an anaerobic pond. Nahid et al. showed that increasing the phenol concentration within the range 0-200 mg/l, the COD removal rate is reduced due to a toxic effect of phenol on the microbial activity [36]. Gonzalo et al. [37] showed that the phenol removal efficiency from synthetic wastewater in anaerobic continuous fluidized-bed bioreactor (6 h retention times) was in the range of 85 to 96 %. Avelar et al. [38] showed that increasing the concentration of phenol in influent wastewater reduced the removal efficiency of the pond.

Optimal conditions resulting from this study was evaluated considering the performance of anaerobic and facultative ponds in oil wastewater treatment and the decrease in the phenol concentration in the output. The highest efficiency of phenol removal in this study was obtained for phenol concentration of 100 mg/l (98.0%) for 10 days retention time, which was above UV/TiO_2 and ELM processes, while less than RBC and AGSBR biological systems. The remarkable level of efficiency achieved should however be noted, since in the stabilization pond phenol was removed up to permissible standards of discharge into the environment for all considered phenol amounts.

The DOW chemical company (Midland, Michigan) has shown that phenol can be used as nutrient by bacteria (without having toxic effects on bacteria up to 500 mg /l concentration). Studies with this compound and also with formaldehyde have already determined the toxicity threshold limit for the mentioned bacteria. Below the toxicity threshold, bacteria use phenols as nutrient, while above the toxicity threshold level, phenol entails extremely toxic effect on them and hence adapted microorganisms should be used [39]. It can be therefore concluded that with the increase in phenol concentration, the anaerobic stabilization pond system performance is reduced due to the increased toxicity of phenol.

In brief, it can be concluded that, if properly operated, stabilization ponds show favorable performances in removing phenol in a wide range of concentrations and a wide range of retention times.

4. CONCLUSIONS

Considering the good characteristics of this system, such as flexibility, ease of performance, simplicity of operation and relatively good efficiency, this system can be used as a replacement for rather expensive and complex systems such as active sludge, etc. Finally, apart from the decrease in the efficiency of stabilization ponds in removing organic carbon materials and consequently reducing the amount of phenol (for low initial amounts, 400 mg/l), the stabilization pond system appears an option with proper cost-effectiveness and can be therefore employed for wastewater treatment of petrochemicals and oil refinery wastewaters containing phenol.

The authors have declared no conflict of interest.

REFERENCES

[1] Busca, G., Berardinelli, S., Resini, C., Arrighi L. (2008). Technologies for the removal of phenol from fluid streams: A short review of recent developments. Journal of Hazardous Materials., 160, 265–288.

[2] Basha, K.M., Rajendran, A., Thangavelu, V. (2010). Recent advances in the biodegradation of phenol: a review. Asian J Exp Biol Sci., 1(2), 219–234.

[3] Senturka, H.B., Ozdesa, D., Gundogdua, A., Durana, C., Soylak, M. (2009). Removal of phenol from aqueous solutions by adsorption onto organomodified Tirebolu bentonite: Equilibrium, kinetic and thermodynamic study. Journal of Hazardous Materials., 172, 353–362.

[4] Bu, Q., Lei, H.., Ren, S.J., Wang, L., Holladay, J., Zhang, Q., Tang, J., Ruan, R. (2011). Phenol and phenolics from lignocellulosic biomass by catalytic microwave pyrolysis. Bioresour. Technol., 102, 7004–7007.

[5] Caetano, M., Valderrama, C., Farran, A., Cortina, J.L. (2009). Phenol removal from aqueous solution by adsorption and ion exchange mechanisms onto polymeric resins. Journal of Colloid and Interface Science., 338, 402–409.

[6] Vimal, C., Srivastava, M., Swamy, M., Mall, D., Prasad, B., Mishra, M. (2006). Adsorptive removal of phenol by bagasse fly ash and activated carbon: Equilibrium, kinetics and thermodynamics. Colloids and Surfaces A: Physicochem. Eng. Aspects., 272, 89–104.

[7] Reis, M.T.A., Freitas, O.M.F., Ismael, M.R.C., Carvalho, J.M.R. (2007). Recovery of phenol from aqueous solutions using liquid membranes with Cyanex 923, J. Membr. Sci., 305, 313-324.

[8] Jarboui, R., Chtourou, M., Azri, C., Gharsallah, N., Ammar, E. (2010). Time-dependent evolution of olive mill wastewater sludge organic and inorganic components and resident microbiota in multi-pond evaporation system, Bioresour. Technol., 101(15), 5749–5758.

[9] Corbitt, R. A. (2004). Standard Handbook of Environmental engineering., second edition. pp. 507-512.

[10] Beran, B. and Kargi, F. (2005). A dynamic mathematical model for wastewater stabilization ponds. Ecological Modelling., 181, 39–57.

[11] Mara, D. D. and Pearson H. (1986). Artificial freshwater environment: waste stabilization ponds. In Biotechnology. Vol. 8. eds H.-J. Rehm and G. Reed. VCH, Germany., pp. 177-204.

[12] Ghazy, M., El-Senousy, W.M., Abdel-Aatty, A.M., Kamel, M. (2008). Performance Evaluation of a Waste Stabilization Pond in a Rural Area in Egypt. American Journal of Environmental Sciences., 4 (4), 316-325.

[13] Naddafi, K., Hassanvand, M.S., Dehghanifard, E., Faezi, R.D., Mostofi, S., Kasaee, N., Nabizadeh, R., Heidari, M. (2009). Performance evaluation of wastewater stabilization ponds in arak-iran. Iran. J. Environ. Health. Sci. Eng., 6(1), 41-46.

[14] Nelson, K.L., Cisneros, B.J., Tchobanoglous, G., Darby, J.L. (2004). Sludge accumulation, characteristics, and pathogen inactivation in four primary waste stabilization ponds in central Mexico. Wat Res., 38, 111-127.

[15] Mara, D.D. (2004). Domestic wastewater treatment in developing countries, USA. 112, 138.

[16] Rajbhandari, B.K. and Annachhatre, A.P. (2004). Anaerobic ponds treatment of starch wastewater: case study in Thailand. Bioresource Technology., 95, 135–143.

[17] Miguel, P. and Mara, D. (2004). Waste Stabilization Ponds: International Water and Sanitation Center. University of Leeds. Leeds, UK.

[18] APHA., AWWA., WPCF. (2005). Standard method for the examination of water and wastewater. 21th ed. American Public Health Association. Washington DC.

[19] Almasi, A., Pescod, M.B. (1996). Wastewater Treatment Mechanisms in Anoxic Stabilization Ponds. Wat. Sci. Tech., 33(7), 125-132.

[20] Mahassen, M., Azza, M. (2008). Performance Evaluation of a Waste Stabilization Pond in a Rural Area in Egypt. American Journal of Environmental Sciences., 4(4), 316-325.

[21] Moussavi, G.H., Mahmoudi, M. (2008). Biological removal of phenol from strong wastewaters using a novel MSBR. Department of Environmental Health, School of Medical Sciences, Tarbiat Modares University, Tehran, Iran.

[22] Vazquez, I., Rodrıguez, J., Maranon, E., Castrillon, L., Fernandez, Y. (2006). Simultaneous removal of phenol, ammonium and thiocyanate from coke wastewater by aerobic biodegradation. Journal of Hazardous Materials., 137, 1773–1780.

[23] Uygur, A., Kargi, F. (2004). Phenol inhibition of biological nutrient removal in a four-step sequencing batch reactor. Process Biochemistry., 39, 2123–2128.

[24] Naddafi, K., Vaezi, F. (2005). Study of aerated lagoons in treating industrial efflent from industrial Bou-ali zone in Hamedan. Water & Wastewater., 54, 47-57.

[25] Mohammadyari, N., Balador, A. (2008). Performance of MBBR in the treatment of combined municipal and industrial wastewater. Water & Wastewater., 65, 38-46.

[26] Abdelwahab, O., Amin, N.K., l-Ashtoukhy, E.S.Z. (2009). Electrochemical removal of phenol from oil refinery wastewater. Journal of Hazardous Materials., 163, 711–716.

[27] Moussavi, G.h., Heidarizad, M. (2010). Biodegradation of mixture of phenol and formaldehyde in wastewater using a single-basin MSCR process. Journal of Biotechnology., 150, 240–245.

[28] Khan, F., Zain, K.M., Qama,r U.S., Sabir, S. (2009). Biodegradation of phenol by aerobic granulation technology .Water Sci Technol., 59(2), 273- 278.

[29] Gheisari, A., Kazemi, N., farazmand, A. (2003). Performance of a dairy wastewater treatment plant. Water & Wastewater., 46, 60-5.

[30] Tyagi, A., Suid, M.T. (1993). A Pilot Study of Biodegradation of Petroleum Refinery Wastewater in Polyurethane- Attached RBC. Process Biochemistry., 28, 75-82.

[31] Moussavi, G.h., Barikbin, B., Mahmoudi, M. (2010). The removal of high concentrations of phenol from saline wastewater using aerobic granular SBR. Chemical Engineering Journal., 158, 498–504.

[32] Mortaheb, H.R., Amini, M.H., Sadeghian, F., Mokhtarani, B., Daneshyar, H. (2008). Study on a new surfactant for removal of phenol from wastewater by emulsion liquid membrane. Journal of Hazardous Materials., 160, 582–588.

[33] Alemzadeh, I., Vossoughi, F., Houshmandi, M. (2002). Phenol Biodegradation by Rotating Biological Contactor. Biochemical Engineering. J., 11, 19-23.

[34] Rahmani, R. (2006). A survey on the possibility of photocatalistic degradation of phenol using UV/TIO2 process, J. of Water and Wastewater., 58, 32-37.

[35] Ramos, M.S., Dávila, J.L., Esparza, F., Thalasso, F., Alba, J., Guerrero, A.L., Avelar, F.J. (2005). Treatment of wastewater containing high phenol concentrations using stabilisation ponds enriched with activated sludge. Water Sci Technol., 51(12), 257-60.

[36] Nahid, P., Kazemi, A. (2004). The optimization of microorganisms activities in the Tehran oil refinery biological wastewater treatment. J. of Water and Wastewater., 50, 23-28.

[37] Gonzalo, M.S., Martínez, M., Leton, P. (2007). Anaerobic treatment of phenol in a continuous fluidized-bed bioreactor. Proceedings of European Congress of Chemical Engineering (ECCE-6) Copenhagen. 16-20.

[38] Avelar, F.J., Martı´nez-Pereda, P., Thalasso, F., Rodrı´guez-Va´zquez, R., Esparza-Garcıa, F.J. (2001). Upgrading of facultative waste stabilisation ponds under high organic load. Biotechnol. Lett., 23, 1115–1118.

[39] Sawyer, C., McCarty, P., Parkin, G. (2003). Chemistry for Environmental Engineering and Science. 5th Ed. McGraw-Hill Inc, New York, NY. Pp 101-107.

Received: March 31, 2014
Accepted: May 14, 2014

CORRESPONDING AUTHOR

Mehdi Fazlzadeh
Ardabil University of Medical Sciences
School of Public Health
Department of Environmental Health
Ardabil
IRAN

Phone: +984533513428
Fax: +98 4533512004
E-mail: m.fazlzadeh@gmail.com

FEB/ Vol 23/ No 10a/ 2014 – pages 2541 – 2548