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Research Article

EFFICIENCY OF STABILIZATION PONDS UNDER DIFFERENT CLIMATE CONDITIONS IN IRAN

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ABSTRACT
Wastewater stabilization ponds due to tolerating hydraulic and organic shocks, serve as a useful technique for the treatment of urban and industrial wastewater. The ingoing study aims at evaluate the efficiency of wastewater stabilization ponds in different climatic conditions of Iran to remove biological wastewater parameters. Therefore, stabilization ponds in eight cities of Birjand, Gilan gharb, Islam abad gharb, Yazd, Arak, Foolad Shahr, Olang and Parkandabad were selected as index stabilization ponds. Monitoring and sampling from different parts of the treatment plant were carried out for one-year period. Having been the input and output wastewater from treatment plant characterized their efficacy in terms of parameters BOD, COD, TSS, TN and TP were compared. The results showed that, on average, the highest removal efficiency of pollutants in stabilization ponds for BOD was recorded in Gilan Gharb and Yazd (81% and 72%), for COD Gilan Gharb and Yazd (83% and 73%), TSS in Gilan Gharb (87%), TN and TP in Parkandabad and Yazd with (33% and 25%) respectively.

***Keywords**: Efficiency Assessment, Stabilization Ponds, Climatic Zones, SPSS Software and Removal Efficiency*

INTRODUCTION
Unsafe disposal of environmental and industrial wastewater causes water, soil, air and crops contaminations leading to deleterious effects on people's health. The most important action to control emissions of wastewater and reuse of wastewater is to establish and monitor wastewater treatment plants Stabilization ponds thank to their simplicity and operational performance and requiring no mechanical and electrical equipment for wastewater treatment have been received more popularity in comparison with other systems. Another advantage of stabilization ponds is high efficiency removal of pathogenic organisms and tolerance against organic and hydraulic shocks (Farzad, 2000; Nadafi *et al.*, 2009) Wastewater stabilization pond is a natural process through which wastewater passes along various ponds in good quality, removing contaminants and pathogens. Stabilization pond systems in many parts of the world, particularly in developing countries or countries characterized with warm climates, given their low cost, easy maintenance, longer life and optimum ability are considered as the first option to wastewater treatment (Monzavi, 1991).

Literature Review on Total Efficiency of Different Stabilization Ponds
Quazzani *et al.*, (1995), studied performance of three types of wastewater stabilization ponds in the arid climate of Morocco. They aimed to compare the efficiency of three types of ponds, including blue hyacinth pond, facultative pond and anaerobic ponds in warm climates, to removal of organic matter, nutrients and pathogens and parasites, in particular, to be used in agriculture without health hazards. The results showed that water blue hyacinth pond is more effective in lowering the organic load (90% ~ TSS and 78% ~ COD) compared to facultative one. The two stabilization ponds to remove nutrients more efficiently (80% ~ Total P, 60% ~ NH4 and 71% ~ NTK) and performance compared to anaerobic ones and facultative pond was more efficient than blue hyacinth pond. Anaerobic pond showed low removal efficiency for organic loads (less than 40%) and nutrients (less than 20%). Organic load removal efficiency for such a system was less than what was expected. The reason behind this is that the algae

photosynthesis and zooplankton development led to settling suspended solids and bacterial decomposition, preventing the removal of TSS is large extent. In addition, during the summer biomass production is increased with temperature and thermal stratification phenomenon characterized with arid climate of Morocco occurs. On the other hand, the retention time of 50 days in ponds can contribute to the development of this phenomenon (Neder *et al.*, 2002)

Nadafi *et al.*, (2008), had undertaken a stabilization pond system assessment in the Iran. The stabilization pond system was located in the Arak city consisted of two modules number 1 and 2. The main objective of foregoing research was to evaluate the performance of wastewater stabilization pond system considering several problems emerged while utilization these systems. They attempted to upgrade these systems, if necessary. Therefore, in the May to September 2007, experiments to determine the parameters of the raw wastewater and treated wastewater were conducted. The results showed that the average concentration emitted BOD5, COD and SS from primary and secondary facultative stabilization ponds in module number 1 was estimated to be 91.5, 169 and 114 and 70, 160, 123 mg/lit respectively. The facultative initial stabilization pond effluent in the first module is accordance with standards for wastewater reuse in agriculture for concentrations of BOD5 and COD. As for the modulus 2, the average concentration of BOD5, COD and SS of secondary and tertiary facultative wastewater stabilization ponds were estimated to 69, 101, 77, 76, 127, 78 mg/lit respectively. The facultative secondary stabilization pond effluent fulfills all standards for all parameters. As a result, the tertiary facultative stabilization pond can converted to those secondary ones in order to improve the quality and quantity of treated wastewater (Nadafi, 2008).

Herrera (2000) investigated efficiency of stabilization pond system Akosombo in Ghana and the impact of seasonal variations on the quality of the final effluent. Qualitative parameters of wastewater treatment included COD, BOD, SS and fecal coliform, heavy metals and ammonia. The results showed that the removal rates of COD, BOD were about SS, 84, 77 and 71 percent respectively. Ammonia removal rate was nearly 93 percent, while the amount of fecal coliform removal was found to be 99.99 percent. Tests showed that heavy metals such as lead, zinc, chrome and cobalt were in trivial concentrations and less than 0.01 mg/lit. Seasonal variations affect the quality of the final effluent. In rainy seasons, final effluent contamination is less compared to dry a season which is attributed to dilution of the effluent by rainwater (Herrera, 2000).

While studying on the efficiency of stabilization ponds in warm climates, Mara 1987 claimed that to achieve high efficiency in stabilization ponds especially in the hot weather, the pond should be placed in hierarchical series. For example, first an anaerobic pond, facultative pond and then one or more complementary ponds are located at the bottom. He also stated that suggested different equations to design rate stabilization pond, take organic loading and the annual average temperature into account but none of them are suitable to describe the rate acceptable loading, in a wide temperature range, so new models should be extended. (Mara and pearson, 1987; Mara and silva, 1986-1976)

MATERIALS AND METHODS

To establish wastewater treatment plants cannot not address the environmental concerns alone, but to achieve the desired environmental standards its efficiency should be continuously monitored. The parameters for evaluating the efficacy of wastewater treatment plants to determine the effect of loading rate of organic matter in the pond include chemical oxygen demand, biological oxygen demand, suspended solids; Wastewater dissolved solids, total nitrogen and phosphorus inputs and outputs from WTP (Melidis *et al.*, 2008; Cirija *et al.*, 2005). In this study, 13 cities in different climates in the country were studied. One of the important issues in deciding how to choose an option from among several available options according to the criteria proposed for the selection. Even if that choice is not desired it may be needed to know what our priority is. In this context and in order to select the index treatment plants in different climatic conditions it is necessary to perform experiments on them, where the Analytical Hierarchy Process AHP was used. Analytical Hierarchy Process (AHP) is an approach that allows making correct decisions in the presence of both qualitative and quantitative criteria and both of them. Considering all aspects of goal, criteria and alternatives, the priorities and importance were determined, 13 cities were compared in terms of criteria separately in paired manner and the relative weight of each criterion was determined. Then criteria weights were measured and their composition was specified by the final weight and ultimately eight cities in three different climates were considered as follows:

- Arak and Islamabad (reprehensive of the cold temperate climates)
- Foolad Shahr, Birjand, Olang and Parkandabad (representative of the warm temperate climates)
- Yazd and Gilan Gharb (representative of the hot climate)

Introduction of the Treatment Plants

Birjand, Arak and Islamabad treatment plants each one composed of two modules. As for Birjand, each module consists of a single debris filtering and one anaerobic unit, facultative pond and complementary pond. Arak treatment plant consists of two modules and a stabilization pond method modulus method is activated sludge. As for Islamabad, each module is characterized with an anaerobic, primary and secondary facultative pond and the chlorination unit. Foolad shahr WTP stabilization ponds include anaerobic ponds in 8-rows, four facultative ponds in double rows and two complementary ponds. Gillan Gharb WTP consists of two anaerobic ponds, three facultative ponds and an aeration pond and a chlorination unit. Yazd treatment plant consists of a single anaerobic unit, facultative pond and then complementary pond. For Parkandabad, four anaerobic ponds and six facultative ponds and Olang WTP included 4 primary and 2 secondary facultative ponds (Pars, 2012-2013) (Figure 1 and Table 1).

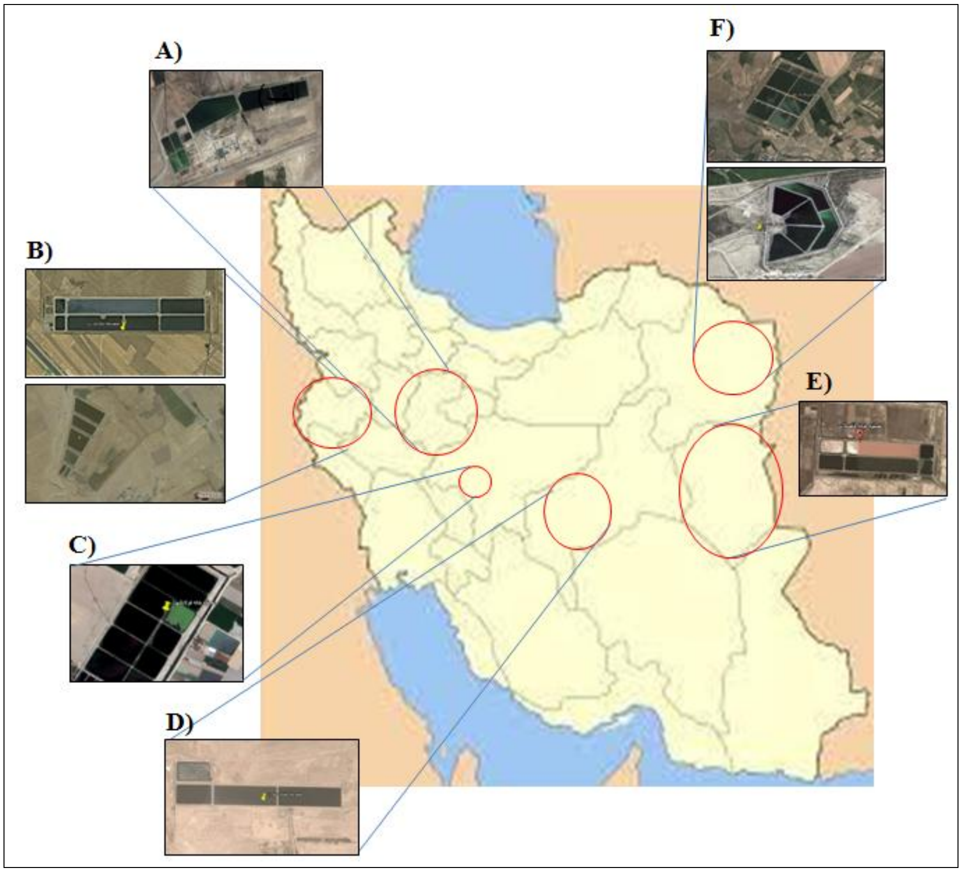

Figure 1: The location of the treatment plants in Iran. A) Arak treatment plants B) Gilan gharb and Eslam abad treatment plants C) Foolad shahr treatment plants D)Yazd treatment plants E) Birjand treatment plants F) Olang and Parkand abad treatment plants

Table 1: Physical characteristics of the selected wastewater treatment plants

Area (m^2)	Depth (m)	Volume (m^3)	Parts of Treatment Plants	City
1768	4.25	5200	Anaerobic pond 1	Arak
1768	4.25	5200	Anaerobic pond 2	
1768	4.25	5200	Anaerobic pond 3	
5304	-	1560	All Anaerobic pond	
20800	3.5	33280	Facultative pond 1	
20800	3.5	33280	Facultative pond 2	
83200	-	133120	All Facultative pond	
3200	3.5	9975	Anaerobic pond	Gilan Gharb
6400	-	19950	All Anaerobic pond	
41000	1.8	67300	All Facultative pond	
22100	1	21460	Maturation pond	
1500	2	3000	Anaerobic pond	Foolad Shahr
12000	-	24000	All Anaerobic pond	
15000	1.9	28500	Facultative pair pond	
10000	1.9	19000	Facultative odd pond	
100000	-	190000	All Facultative pond	
18750	1.8.	33750	Maturation pond	
37500	-	67500	All Maturation pond	
26800	5	129500	Anaerobic pond	Yazd
47300	2	92600	Initial Anaerobic pond	
47300	2	92600	Secondary Anaerobic pond	
94600	-	185200	All Anaerobic pond	
158700	4	136350	Initial Facultative pond	Olang
84500	4	106900	Secondary Facultative pond	
74128	4	260000	All Anaerobic pond	Parkandabad
574000	1.8	800000	All Facultative pond	
9400	4.5	38902	Anaerobic pond 1	Birjand
9400	4.5	38902	Anaerobic pond 2	
18800	-	77804	All Anaerobic pond	
56700	2	107000	Facultative pond 1	
56700	2	107000	Facultative pond 2	
7500	4	28920	Anaerobic pond	Islamabad
15000	-	57840	All Anaerobic pond	
68500	1.7	114300	Initial Facultative pond	
137000	-	228600	All Initial Facultative pond	
32850	1.3	41870	Secondary Facultative pond	
65700	-	83740	All Secondary Facultative pond	

The present research was carried out on raw sewage and effluent treatment plants over a period of one year. Therefore, to evaluate the performance of the treatment plant, the during a one-year period of monitoring and sampling from different parts of the plant have been attempted. A test on samples BOD, COD, TSS, TP and TN was done using standard methods of water and wastewater tests (APHA, ANNA,WEF, 1992) finally, Kolmogorov – Smirnov test was used to evaluate the efficiency of the treatment plant.

Results of Stabilization Ponds Efficiency in Pollutants Removal

Table below presents results of the analysis of parameters BOD, COD, TSS, TN and TP. It should be noted that a total of 317 cities in the sample was tested. (Tables 2 to 9)

Table 2: Results of the analysis of raw sewage and effluent to Parkandabad treatment plant

Efficiency of treatment	Facultative pond	Anaerobic pond	influent			City
	148.5	444.86	685.75	Average		
79	18.61	18.15	124.23	Standard deviation	BOD	
	67	35	-	Efficiency		
	254.5	571	1094	Average		
77	24.08	16.2	241.03	Standard deviation	COD	
	31	47	-	Efficiency		
	110.08	129.16	507.83	Average		
79	16.81	16.68	66.51	Standard deviation	TSS	Parkandabad
	15	74	-	Efficiency		
	55.71	84.15	-	Average		
33	24.47	13.45	-	Standard deviation	TN	
	34	-	-	Efficiency		
	6.02	7.16	-	Average		
16	1.15	2.23	-	Standard deviation	TP	
	16	-	-	Efficiency		

Table 3: Results of the analysis of raw sewage and effluent to olang treatment plant

Efficiency of treatment	Maturation pond	Facultative pond	Anaerobic pond	influent		City	
	148.33	-	-	479	Average		
70	13.5	-	-	80.68	Standard deviation	BOD	
	69	-	-	-	Efficiency		
	274.91	-	-	851	Average		
68	45.2	-	-	144.84	Standard deviation	COD	
	68	-	-	-	Efficiency		
	109.25	-	-	507.33	Average		
79	14.7	-	-	105.78	Standard deviation	TSS	Olang
	78	-	-	-	Efficiency		
	57.96	-	-	74.21	Average		
22	25	-	-	5.86	Standard deviation	TN	
	22	-	-	-	Efficiency		
	6.6	-	-	7.8	Average		
25	1.42	-		1.79	Standard deviation	TP	
	15	-	-	-	Efficiency		

Table 4: Results of the analysis of raw sewage and effluent to Birjand treatment plant

Efficiency of treatment	Maturation pond	Facultative pond	Anaerobic pond	influent			City
	109.5	133.55	238.82	558.7	Average		
80	17.3	29.26	36.5	99.92	Standard deviation	BOD	
	18	44	57	-	Efficiency		
	275.96	371.66	416.62	896.33	Average		
70	20.3	35.4	83.34	155.12	Standard deviation	COD	
	26	11	54	-	Efficiency		
	71.68	65.19	-	253.95	Average		
71	23	22.81	-	29.31	Standard deviation	TSS	**Birjand**
	-10	74	-	-	Efficiency		
	65.53	-	-	88.18	Average		
26	12.9	-	-	9.98	Standard deviation	TN	
	26	-	-	-	Efficiency		
	9.8	-	-	11.8	Average		
17	2.3	-	-	6.88	Standard deviation	TP	
	17	-	-	-	Efficiency		

Table 5: Results of the analysis of raw sewage and effluent to yazd treatment plant

Efficiency of treatment	Maturation pond	Facultative pond	Anaerobic pond	Influent		City	
	-	74.51	120.37	267.5	Average		
72	-	7.26	23.93	35.08	Standard deviation	BOD	
	-	72	55	-	Efficiency		
	-	170.31	252.48	631.21	Average		
73	-	29.16	58.25	92.85	Standard deviation	COD	
	-	73	60	-	Efficiency		
	-	105.16	168.09	347.5	Average		
11	-	11.06	28.93	80.52	Standard deviation	TSS	yazd
	-	37	51	-	Efficiency		
	-	36.2	45.6	-	Average		
20	-	21.05	-	-	Standard deviation	TN	
	-	28	-	-	Efficiency		
	-	6.1	8.1	-	Average		
25	-	1.8	-	-	Standard deviation	TP	
	-	24	-	-	Efficiency		

Table 6: Results of the analysis of raw sewage and effluent to Gilan gharb treatment plant

Efficiency of treatment	Maturation pond	Facultative pond	Anaerobic pond	Influent		City	
	40	50	105.4	210	Average		
81	15	20.36	72.62	54.32	Standard deviation	BOD	
	20	53	50	-	Efficiency		
	78.9	103	236	472	Average		
83	41.81	78.34	93.36	188.83	Standard deviation	COD	
	83	56	50	-	Efficiency		
	84.4	94.2	140	259.6	Average		
87	15.51	25.65	70.27	195.12	Standard deviation	TSS	**Gilan gharb**
	10	33	46	-	Efficiency		
	29	-	-	38	Average		
23	11.2	-	-	-	Standard deviation	TN	
	23	-	-	-	Efficiency		
	3	-	-	4	Average		
25	1.1	-	-	-	Standard deviation	TP	
	25	-	-	-	Efficiency		

Table 7: Results of the analysis of raw sewage and effluent to Eslam Abad treatment plant

Efficiency of treatment	Maturation pond	Facultative pond	Anaerobic pond	influent		City	
	47.5	52.25	184.12	230.14	Average		
80	20.35	19.65	68.34	53.65	Standard deviation	BOD	
	9	72	20	-	Efficiency		
	88.12	96.81	350.28	483.5	Average		
82	45.13	25.63	90.99	190.85	Standard deviation	COD	
	9	72	28	-	Efficiency		
	80.71	90.28	130.57	226.71	Average		
64	7.27	14.62	59.65	177.55	Standard deviation	TSS	Eslam Abad
	11	31	42	-	Efficiency		
	36.5	-	-	41.5	Average		
20	22	-	-	-	Standard deviation	TN	
	12	-	-	-	Efficiency		
	4.22	-	-	5	Average		
20	1.9	-	-	-	Standard deviation	TP	
	15	-	-	-	Efficiency		

Table 8: Results of the analysis of raw sewage and effluent to Arak treatment plant

Efficiency of treatment	Maturation pond	Facultative pond	Anaerobic pond	influent		City	
	-	80	160	235	Average		
66	-	19.65	35.89	74.53	Standard deviation	BOD	
	-	56	32	-	Efficiency		
	-	109	273	391	Average		
55	-	25.63	92.85	161.71	Standard deviation	COD	
	-	35	30	-	Efficiency		
	-	90	156	170	Average		
47	-	14.52	28.13	102.97	Standard deviation	TSS	**Arak**
	-	42	7	-	Efficiency		
	-	41.51	43.5	45.85	Average		
11	-	24.47	55.71	9.94	Standard deviation	TN	
	-	5	5	-	Efficiency		
	-	5.69	6	6.14	Average		
14	-	1.15	1.78	2.59	Standard deviation	TP	
	-	5	2	-	Efficiency		

Table 9: Results of the analysis of raw sewage and effluent to foolad shahr treatment plant

Efficiency of treatment	Maturation pond	Facultative pond	Anaerobic pond	influent		City	
	-	58.33	304.83	-	Average		
81	-	18.06	54.12	-	Standard deviation	BOD	
	-	81	-	-	Efficiency		
	-	181	631.33	-	Average		
71	-	26.59	120.51	-	Standard deviation	COD	
	-	71	-	-	Efficiency		
	-	74	235	-	Average		
69	-	20.21	38.17	-	Standard deviation	TSS	**Foolad shahr**
	-	69	-	-	Efficiency		
	-	44.41	58.45	-	Average		
24	-	17.2	18.6	-	Standard deviation	TN	
	-	24	-	-	Efficiency		
	-	7.52	9.91	-	Average		
20	-	1.52	1.86	-	Standard deviation	TP	
	-	24	-	-	Efficiency		

The above table reveals that the BOD level in is Birjand 17.3 ± 109.5, in Yazd 7.26 ± 74.51, Gilan Gharb 15 ± 40, Islamabad 20.35 ± 47.5, Parkandabad 18.61 ± 148.5, Olang 13.5 ± 148.33, Arak 18.06 ± 58.33 and Foolad Shahr is 65 ± 80.

The COD level in is Birjand 275.96±20.3, in Yazd 170.31±29.16, Gilan Gharb 78.6±41.81, Islamabad 88.12±45.13, Parkandabad 254.5±24.08, Olang 274.91± 45.2, Arak 80 ± 19.65and Foolad Shahr is 177 ± 25.63.

The TSS level in is Birjand 71.68±23, in Yazd 105.16±11.06, Gilan Gharb 84.4±15.51, Islamabad 80.71±7.27, Parkandabad 110.08±16.81, Olang 109.25± 14.7, Arak 90 ± 14.52 and Foolad Shahr is 74 ± 20.21.

The TN level in is Birjand 65.53±12.9, in Yazd 36.02±21.05, Gilan Gharb 29±11.2, Islamabad 36.05±22, Parkandabad 55.71±24.47, Olang 57.96± 25, Arak 41.51 ± 24.47 and Foolad Shahr is 44.41± 28.81.

The TP level in is Birjand 98±2.3, in Yazd 6.1±1.8, Gilan Gharb 3±1.1, Islamabad 4.22±1.9, Parkandabad 6.02±1.15, Olang 6.6± 1.42, Arak 5.69 ± 1.15 and Foolad Shahr is 7.52± 1.52.

At the same time, BOD removal efficiency in Birjand, Yazd, Iran, Gilan Gharb, Islamabad, Parkandabad, Olang, Arak and Foolad Shahr were estimated to be 80, 72, 81, 80, 79, 70, 66 and 81 percent respectively.

COD removal efficiency in Birjand, Yazd, Iran, Gilan Gharb, Islamabad, Parkandabad, Olang, Arak and Foolad Shahr were estimated to be 70, 73, 83, 82, 77, 68, 55 and 71 percent respectively

TSS removal efficiency in Birjand, Yazd, Iran, Gilan Gharb, Islamabad, Parkandabad, Olang, Arak and Foolad Shahr were estimated to be 71, 11, 87, 64, 79, 79, 47 and 69 percent respectively

TN removal efficiency in Birjand, Yazd, Iran, Gilan Gharb, Islamabad, Parkandabad, Olang, Arak and Foolad Shahr were estimated to be 26, 20, 23, 20, 33, 22, 11 and 24 percent respectively

TP removal efficiency in Birjand, Yazd, Iran, Gilan Gharb, Islamabad, Parkandabad, Olang, Arak and Foolad Shahr were estimated to be 17, 25, 25, 20, 16, 25, 14 and 20 percent respectively

The results of these studies suggest that, on average, the highest percent removal of BOD and COD parameters were related to cities located in warmer climates. The rate of BOD and COD removal in Gilan Gharb and Yazd were 81% and 72%, 83% and 73% respectively. On the other hand, the highest percentage TSS removal in Gilan gharb was 87 percent. As for TN, results showed that the maximum removal efficiency of 33% in Parkandabad and as for TP removal rate in Yazd, Gilan Gharb and Olang were found to be 25 percent.

Generally, high removal efficiency in hot climates largely is due to higher temperatures in the summer, and biological processes are increasing. On the other hand, longer days and more sunlight hours in lagoons and algal activity is another factor in this event. The lowest removal rate is attributed to the minimum retention time and maximum loading rate in system. However, the stabilization ponds studied in different climates the average temperature of the incoming wastewater treatment plant index with temperature are variable. Although temperatures in the hot and cold seasons in the survey cities varies between 18 and 24 degrees, but the temperature difference between the warm and cold seasons varies in 6 to 10 degrees.0

RESULTS AND DISCUSSION

Relationship Between Organic Loading and Efficiency of BOD Removal in Stabilization Ponds

Given the differences in facultative ponds organic loading in different climatic conditions a relation between organic loading rate and efficiency of BOD removal in anaerobic and facultative ponds were determined. As it is deduced from Figures 6 and 7 at loading less than 200 kg / ha. day BOD removal efficiency in secondary ponds between 60 to 70 percent with a tolerance of 3 ± and dropped proportional to the quality of effluent to less than 80 mg per liter. This dependence is directly related to residence time in the lagoon so that in residence time between 15 to 20 days, BOD removal efficiency increased to 70 percent.

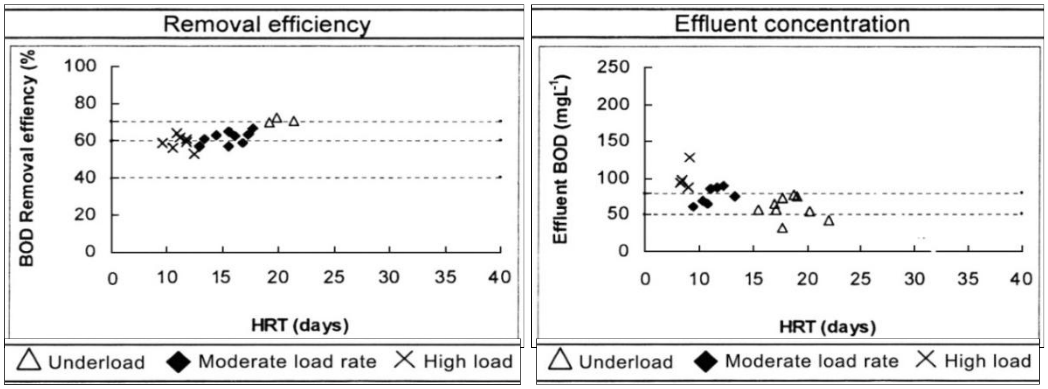

Figure 6: Correlation graph between HRT and concentrations of BOD and BOD removal efficiency in secondary facultative pond

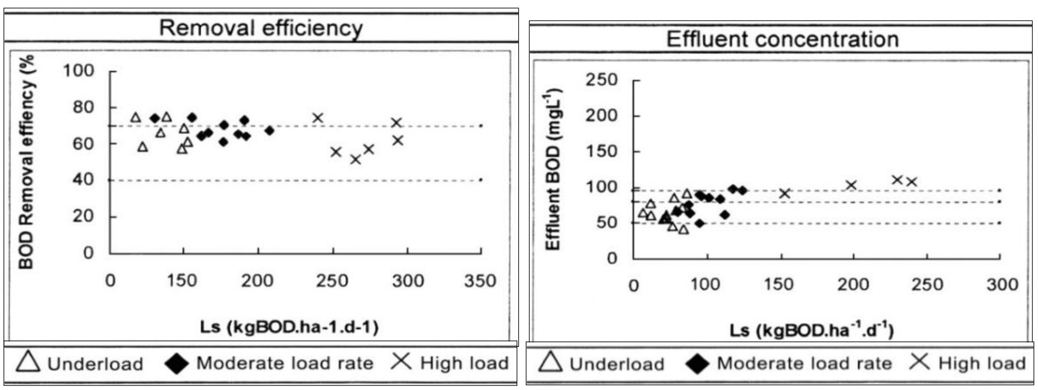

Figure 7: Correlation graph between Ls and concentrations of BOD and BOD removal efficiency in secondary facultative pond

On the other hand, according to Figure 8, the BOD removal efficiency of 40 to 50 percent in loading less than 100 kg / m3.day was reported in anaerobic ponds.

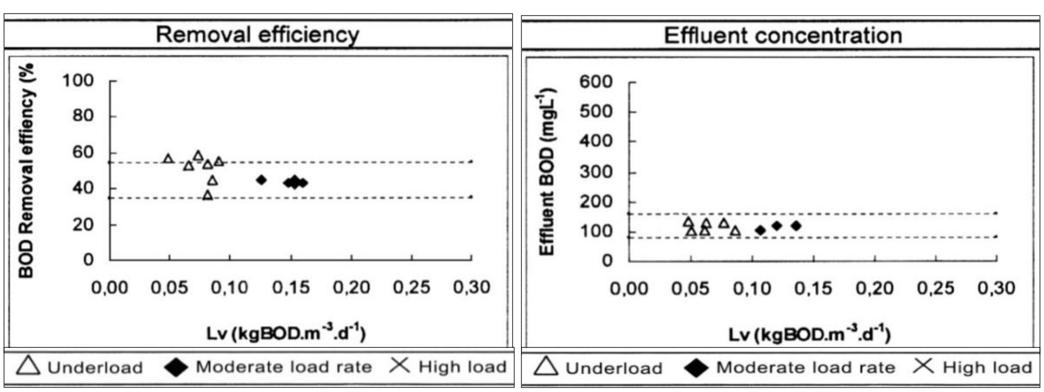

Figure 8: Correlation graph between density and removal efficiency of BOD in anaerobic ponds

Figure 9 shows the relationship between the concentrations of BOD and DO in facultative lagoons. This means that as the more concentration of DO the less BOD concentration will be (When they DO concentration is greater than 4 mg per liter BOD level is reduced to below 100 milligrams per liter).

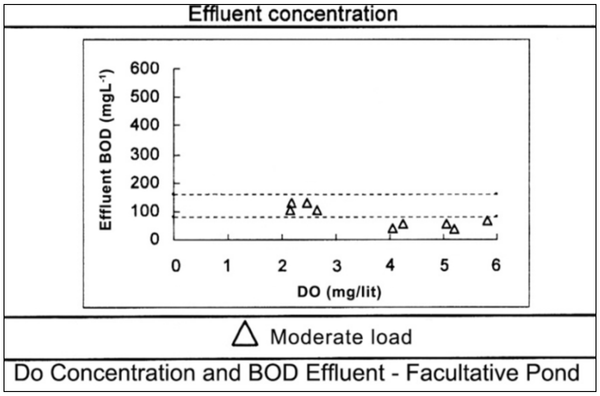

Figure 9: Correlation between DO and BOD concentration of facultative ponds

Conclusion

As a whole and given integrated graphs on different parameters, the overall results were as follows:

1. Pond efficiency under different climatic conditions for parameter were estimated to be BOD =% 50-75 ± 5, COD =% 48-70 ± 7, TSS =% 42-60 ± 10, TP, TN =% 15-25 ± 3 was it is.

2- The loading rate and residence time exert a direct linear impact oxygen concentration in lagoon.

1. under higher loadings with low DO, BOD differences caused by TSS can stems from the withdrawal of the dissolved sediments is anaerobic and facultative units.

2- In some cases, given different loads in stabilization ponds, the difference between soluble and insoluble BOD is high mainly due to the presence of algae in wastewater. This factor also affects emitted COD.

3. Phosphorus evaluation showed that temperature changes caused by climate change impacts on nutrient removal rates.

4- The results of removal efficiency of ammonia nitrogen in stabilization ponds, removal of this parameter are significantly influenced by temperature. In warm climates, concentration of ammonia nitrogen in stabilization ponds is low due to DE nitrification and microorganisms' absorption. While in cold climates, especially during the winter due to low temperatures, DE nitrification is reduced. As a result, the concentration of ammonia nitrogen in stabilization ponds rises significantly.

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