Abhath Journal of Basic and Applied Sciences., 2(1) (2023) 29-33

Abhath Journal of Basic and Applied Sciences

Website:https://ojs.abhath-ye.com/index.php/OJSRJBAS/about

doi:https://doi.org/10.59846/ajobas.v2i1.450

Research paper, Short communication, Review, Technical paper

Wastewater treatment plant assessment and potential reuse: A case study in Hodeidah (Yemen)

Abdulbari A. Ahmad[1*], Ali B. AL-Zubaidy[2], Hani A. Dammag[3]

[1,2] *Department of Chemical Engineering, Faculty of Engineering, Hodeidah University, Yemen.*

[3]*Department of Chemistry, Facility of Science, Sana'a university, Yemen*

***Corresponding author E-mail:** alborani_75@yahoo.co.uk*

Received:07 June 2023. Accepted: 01 July 2023. Published 05 July 2023.

Abstract

Using waste stabilization ponds for wastewater treatment is an effective, low-cost, and low-maintenance operation. All surface water and groundwater resources in Yemen are being exploited beyond the recharge level, resulting in a water crisis. Reusing treated wastewater for irrigation could mitigate this water crisis. Analyzing the quality raw and treated wastewater of Hodeidah city's Wastewater Treatment Plant (WWTP) by waste stabilization ponds is the objective of this study. A comparison of the results of pH, EC, SS, COD and BOD5 with Yemen and international standards shows that WWTP influent and effluent meet acceptable standard limits for irrigation. According to the wastewater parameters analyzed, the suspended solids, COD, and BOD5 levels in influent and effluent were 380-180, 757-175 and 450-84 mg/l, respectively. As a result, the wastewater treatment plant in Hodeidah city can be used for unrestricted irrigation as it poses a low risk of impacting the surrounding environment.

***Keywords**: Wastewater treatment plant; Stabilization Pond; Reuse of wastewater; Assessment*

1. Introduction

As part of the Arab Spring revolutions, Yemen's water crisis has worsened since the start of the uprising in February 2011. A large-scale civil war is raging in Yemen today, resulting in deaths and injuries, displacements, and a lack of security. Food insecurity, high food prices, and diminishing resources are all contributing to the acute water crisis [1, 2]. Yemen's population reached 26,687,000 in 2015, and the population is expected to reach 50,000,000 in 2037. Yemen is considered one of the countries most affected by pollution in the Arabian Peninsula, or rather, one of the most polluted countries in general. Many sources of pollution can lead to health problems and affect a person's quality of life. Factory residues and wastewater are among the sources that affect human health. Raw sewage production is approximately 70–100 million m^3, treated sewage production is 46 million m^3, and of the 31.2 million m^3 used for irrigation, 99.9% are used for surface irrigation [3]. In sewage effluents, a variety of pathogenic microorganisms can be found, with bacteria, viruses, and parasites being the most common. The treatment and disposal of wastewater in cities are somewhat complicated, since many methods are available to treat polluted water. Water pollution is mainly caused by poor sanitation and poor wastewater quality from sewage treatment plants. Wastewater treatment facilities must dispose of treated wastewater as part of their planning and design. Effluent treated with wastewater is either reused or discharged into the environment after treatment. In terms of wastewater reuse and safety control, Yemen is the least developed among the Arab countries, as it is primarily rural, has limited sewage connections, and has degraded WWTPs that do not meet national quality requirements and have uncontrolled reuse patterns. UNICEF (2013) reports that 2,000 children under five in the world die every day due to diarrhoea, 90% of the deaths have been directly linked to poor sanitation and contaminated water sources [4]. Water-borne diseases threaten 75% of the population, 55,000 children die from water-borne illnesses annually, and three million people contract hepatitis because of unclean drinking water, according to an unpublished report by parliament's water and environment committee [5]. The characteristics of wastewater treatment plants in Yemen are shown in Table 1.

There is a difference between cities in the quality of the treated water provided by WWTPs. According to the treatment method as well as the WWTP capacity and operating conditions, the wastewater quality in Hajjah is very good, while in Taiz it is very poor. In general, wastewater quality is poor since none of the existing WWTPs produce wastewater that complies with the regulations. Research on the efficiency of wastewater treatment plants in Yemen based on microbiological analysis is extremely limited. A report indicated that most animals in the vicinity of the SWWTP were suffering from intestinal diseases caused by pathogenic bacteria in the sewage, including swelling of the stomach, liver calcification, changes in milk taste, intestinal worm's diarrhea, and mouth blisters. As a result of not using plant gloves when monitoring sewage irrigation in these areas, farmers in these areas are also suffering from dermalogical canal diseases and mouth blisters caused by pathogenic bacteria [3]. The reports depended on COD and BOD measurements due to the lack of equipment in Yemeni laboratories. The quality of the treated wastewater is shown in Table 2

Table 1 Treated water quality of wastewater treatment plants in Yemen [6].

Parameter	Sana'a	Aden	Dhamar	Hodeida	Yemen standards
BOD (mg/l)	24	N.A.	102	106	150
COD (mg/l)	103	N.A.	189	348	500
TDS (mg/l)	1852	1695	700	3110	450–3000
SS (mg/l)	28	N.A.	580	128	50
FC/100 ml	12,000	80,000	110,000	1366	<1000

Reusing treated wastewater depends on the purity of the wastewater and the conformity of the laboratory tests with Yemen's standards. Approximately 15,000 hectares of Yemen are irrigated with wastewater, whether it is treated or not. There are, however, serious risks associated with the reuse of agricultural raw sewage, including risks to public health, livestock, and the environment. More than 27 wastewater treatment plants have been installed in Yemen's main cities to handle 33,5 million m^3 of wastewater. However, most of them lack maintenance and malfunction, which affects the quality of treated water.

Table 1 Characteristics of wastewater treatment plants in Yemen [6].

Station	Design capacity (m3/d)	Type of treatment	Actual flow (m3/d)	Cost of treatment (U.S.$/m3)	Disposal method	Disposal sludge
Sana'a	50,000	Activated sludge	37,000	0.25	Irrigation	Fertilizer
Taiz	17,000	W.S.P. biological ponds	17,000	0.03	Irrigation	Fertilizer
Hodeida	18,000	W.S.P. biological ponds	18,000	0.03	Sea + irrigation	Fertilizer
Aden	70,000	W.S.P. biological ponds	17,000	0.03	Sea + irrigation	Fertilizer
Ibb	7000	Activated sludge	7000	0.25	Irrigation	Fertilizer
Dhamar	10,000	W.S.P. biological ponds	6000	0.03	Irrigation	Fertilizer
Hajja	5000	Trickling filter	1150	NA	Irrigation	Fertilizer
Mukalla	8000	W.S.P. biological ponds	6000	0.025	Sea	Fertilizer
Rada'a	2800	W.S.P. biological ponds	1500	0.025	Irrigation	Fertilizer

Hodeida has experienced rapid growth in recent years. As well as rapid urbanization, it experienced a boom in industrial development. The situation is accompanied by very high water demands for human consumption, industry, and agriculture. The increased demand for water is met mainly by groundwater, which may be exhausted due to overexploitation. Moreover, socioeconomic development is accompanied by an increase in wastewater discharges as well as pollution generated by these discharges in surface water, groundwater, and the environment. The treatment plant significantly helps in the reduction of disposal of raw sewage, risks of groundwater pollution and the spread of excreta-related diseases [7]. This work is focused on evaluating the wastewater quality and validity of agricultural irrigation using the wastewater treatment plant in Hodeida city. This study aims to assess the water treatment plant (WWTP) in Hodeida. In addition, evaluate whether the quality of the effluent treated at Hodiedah's WWTP meets Yemeni's (150/2001) and international standards [8, 9].

2.0 Materials and Methods

2.1 The Study Area

More than 27 wastewater treatment plants have been installed in Yemen's main cities to handle 33,5 million m^3 of wastewater. However, most of them lack maintenance and malfunction, which affects the quality of treated water. The Figure 1 shows the locations of WWTPs in Yemen's cities.

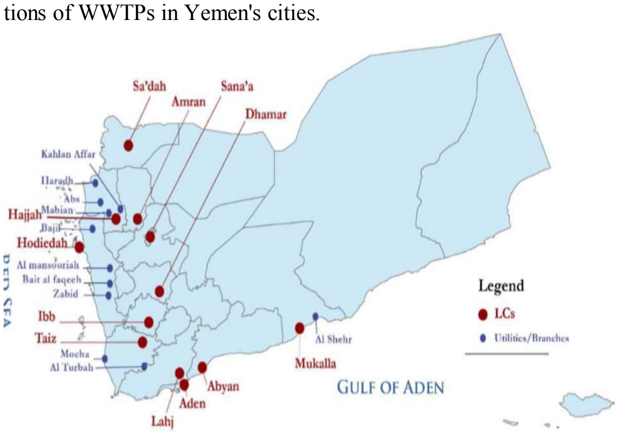

Figure1. Map of Yemen show the cities of WWTPs.

Hodeida's first large sewerage treatment plant was commissioned in 2017. The plant has a mean design capacity of 18,000 m^3/d and an actual flow rate of 18,000 m^3/d. An area of 22 ha is shown in Figure 1 for the WSP. Wastewater flows under the influence of gravity from the inlet to the outlet of the sewage treatment plant, which employs a system of waste stabilization ponds.

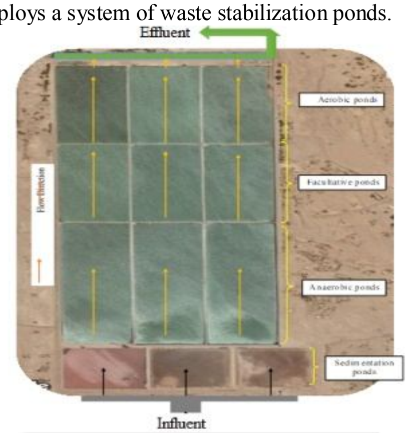

Figure 1. WSPs in city of Hodeida.

2.2 *Sample collection*

The performance of the WSP was analyzed by taking samples from the pond influent (raw sewage) and from the effluent of the ponds. The samples were collected twice a month for a period of 1 year to study the effect of seasonal variation on the performance of WSP. Monthly and seasonal averages were calculated for the sewage samples to assess the pond treatment performances. All samples were analyzed for five-day at 20 °C Biological Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Electrical Conductivity (EC), pH, Total Dissolved Solids (TDS), Suspended Solids (SS), Temperature, pH, Fecal Coliforms (FC), Dissolved Oxygen (DO) were analyzed in the WWTP laboratory located on site at Hodeida city. Tests, including BOD and COD, were conducted in accordance with American Standard Methods [10]. The sampling of all inflows and outflows took place between 9 and 10 am (local time).

3.0 Results and discussion

This study assesses the performance of WWTP by waste stabilization ponds of Hodeida city by analyzing the quality raw and treated wastewater predominantly by domestic sewage.

3.1 Evaluation of Parameters effect of WWTP

The assess the last analysis (21/07/2021) parameters effects of WWTP by waste stabilization ponds as the fallowing:

3.1.1 pH

The pH increases slightly from the inlet to the outlet of the WWTP, 7.6 to 8.80, respectively. The pH range in the raw and treated wastewater increases the bacterial growth required for the biological degradation of organic pollutants [11]. According to the results, wastewater stabilization ponds should have a pH range of 7.6 to 8.8. In general, the average pH value in purified water (7.6) shows no adverse effect on the water quality of the receiving environment. Agronomically, values of treated water between pH 6.5 and 8.4 are recommended for irrigation by Yemeni standards [12], and international standards [13].

3.1.2 Electrical Conductivity (EC)

According to the results recorded during this study, raw sewage at the entrance to the WWTP has an electrical conductivity (EC) value of 5370 µS/cm. The conductivity values of treated water at the outlet of the WWTP vary from 5970 µS/cm. These results show that the conductivity increases slightly during the wastewater treatment, with 5370 µS/cm at the inlet and 5970 µS/c at the outlet of the WWTP. This is consistent with the work of Franck [12]. There is little difference in conductivity between raw and treated water as a result of physical and biological treatments. Agronomically, the range of electrical conductivity values recorded in the treated water by WWTP is in the range of values (400-6000µS/cm) recommended for irrigation water by the Yemeni national standard and the international standard [13]. However, the use of electrical conductivity alone to evaluate the risk to reuse is not enough.

3.1.3 Total Dissolved Solid

Table 3 shows the values of Total Dissolved Solid (TDS) influent, and effluent are 3490 and 3880 mg/l respectively. Agronomically, the range of levels of suspended solids obtained (mean of 70 mg/l) in the treated water greatly exceeds the normal of 30 mg/l recommended for irrigation water [9] and discharge in the surface water by WHO [8]. However, these high levels do not interfere with the use of such water in crop irrigation. According to Westcott and Ayers [13], the maximum permissible value can reach 2000 mg/l of TSS. The use of waters with such a load should be done carefully to avoid clogging the soil porosity to the adverse effects on the permeability.

3.1.4 Dissolve Oxygen

The Dissolved Oxygen (DO) concentration within facultative ponds increases with increasing light penetration through the pond surface [14]. For a pilot-scale system, the maximum DO concentration due to photosynthesis may occur between 1.00 pm and 3.00 pm when the DO could be as high as 20 mg/l [15]. Therefore, sunlight and solar radiation have a great implication on WSP treatment performance [16, 17]. Most facultative ponds in Hodeida were pink in color, and the odor was released. The pink color indicates that the facultative ponds are over-loaded and mostly anaerobic [18]. The amount of DO measure at different depths of the facultative ponds is increased to between 0.2 to 5.2 mg/l. However, in the treatment of wastewater by WSPs, the DO contained in the treated water should be more than 2 mg /l.

3.1.5 Chemical Oxygen Demand

The Chemical Oxygen Demand (COD) is commonly used to indirectly measure the organic compounds in water/wastewater. As COD can determine the organic pollutants found in surface water, it is known as a useful measurement of water quality. Therefore, COD measures the potential overall oxygen requirements of the wastewater sample including oxidizable components. Wastewater treatment plants have serious environmental problems of high COD. As a result of the pharmaceutical, food processing, and service station's connection to the sewage system of the city of Hodeida, complex organic molecules are discharged into the sewage system, which affects the WWTP. However, the analysis of results obtained from this study from 2020 to 2021. Table 3 shows the values of COD, are much higher than the values planned in the design of WWTP. Based on Table 4, removal efficiencies of COD by WWTP between 2020 and 2021 are respectively 64.28 of 8%, 84.38% of 73.86% of 24.47% of 49.16% of 76.88%.

3.1.6 Biological Oxygen Demand

Although biological treatment is generally efficient in removing Biological Oxygen Demand (BOD5) and suspended solids, it is considered unsatisfactory because of its low efficiency and low reaction rate. However, the analysis of results obtained from this study the values of BOD5, are much higher than the values planned in the design of WWTP. Based on Table 4, removal efficiencies of BOD by WWTP between 2020 and 2021 are respectively 84.88%, 81.33%, 74.03%, 75.03%, 80.31% and 81.33%.

3.1.7 Faecal Coliform

According to Table 3, the final effluent of the WSP contains faecal coliform counts in the range of 400 to 700 CFU/100 ml. These numbers are well above the global guideline threshold of 1000 CFU/100 ml [18, 19]. It is therefore possible to restrict the use of the treatment plant effluent to irrigation purposes, such as watering sand dunes and trees within Hodeidah greenbelt [20].

3.2 Inflow Wastewater Analysis

The characteristics of raw sewage (influent) and treated wastewater (effluent) from Hodeida waste stabilization ponds are summarized as shown in Table 3. The raw wastewater contains relatively high organic matter e.g., BOD and SS loads. Yemen and other arid and semi-arid countries have highly concentrated raw sewage. The mean evaporation for Hodeida during the study period was 9.7 mm/d. In addition, high concentrations are associated with low water consumption rates between 60 and 65 l/cap/d and high temperatures at the same time [20, 21]

3.3 Performance of the Anaerobic Pond

Wastewater stabilization ponds are normally arranged in series rather than in parallel to increase the overall treatment performance [16]. The arrangements usually comprise anaerobic ponds followed by facultative ponds and sometimes also by maturation and/or polishing ponds (Figure 1). This case did not use maturation or polishing ponds study. The purpose of this arrangement is for the anaerobic pond to absorb the high organic loading of the wastewater. The associated BOD5 and SS removal efficiencies of the ponds are usually between 50 and 60%, and sometimes even up to 75%, if they are designed and operated in agreement with international guidelines [16, 21, 22]. Table 3 summarizes the wastewater quality effluent of the facultative ponds (equal to the overall plant effluent) between January 2020 and January 2021. Table 3 indicates that the performance of the anaerobic pond was inefficient. Considerable sludge accumulation in the ponds was observed in Hodeida. Therefore, the accumulation of sludge in the ponds is the main cause of poor effluent quality and lack of removal efficiency. This results in poor treatment performance when large amounts of sludge accumulate at the bottom layers of both anaerobic and facultative ponds. The absence of a desludging programme has a great impact on the performance of a pond by altering its hydraulic regime due to a decrease in the pond's effective volume, change in the shape of the bottom surface, and reduction of the retention time of the ponds [21]. The use of treated wastewater for crop irrigation practices requires periodic sludge removal to maintain long-term self-sustainability and compliance with WHO guidelines. Furthermore, over-loading in terms of the maximum aerial BOD5 load is a frequent reason for the malfunctioning of anaerobic ponds. It follows that the anaerobic pond of the WSP system was under-designed for the current load. It is therefore recommended either to enlarge the existing pond or to construct a second anaerobic pond (Figure 1).

Table 3 Physico-chemical characteristics of raw wastewater (influent) and treated wastewater (effluent) from Hodeida waste stabilization ponds.

Parameter	Unit	12/01/2020		17/03/2020		21/04/2020		02/07/2020		12/01/2021		03/07/2021	
		Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
Temperature	°C	22.4	27	28.2	26.3	25.2	25	29	27.3	27.1	26.3	30.1	29
EC	UMOHS/CM	4500	5326	4880	5630	4400	5800	4620	6320	5470	6270	5370	5970
TDS	Mg/L	2925	3237	3172	3659.5	2860	3770	3003	4105	3556	4076	3490.5	3880.5
pH		7.48	8.43	7.48	8.79	7.6	8.95	7.3	8.74	7.36	8.59	7.64	8.8
SS	Mg/L	276	46	-	-	400	180	-	-	276	62	380	180
Settable matter	Ml/L	10	-	13	-	15	-	4	-	4	-	5	-
DO	Mg/L	0.3	4	-	-	0.2	5	0.3	4.5	0.5	6.5	0.2	5.2
COD	Mg/L	560	200	1473	230	792	207	568	429	657	334	757	175
BOD_5	Mg/L	536	81	450	84	362	94	242	60	447	88	450	84
Fecal coliform	CFU/100 ml	-	1000	-	-	-	1200	-	1400	-	1000	-	-
Total coliform	CFU/100 ml	-	6000	-	-	-	14000	-	22000	-	13600	-	-

Parameters	Conductivity	TDS	SS	DO	COD	BOD_5	Total coliform	Fecal Coliform	pH
Yemen standards (150/2001)	700- 4000	450-3000	50	2	500	150	0	<1000	6,5-8,4
International standards	700-3000	1000	<30[2]	-		<30[2]	0	-	6.5-8.4

3.4 Quality of effluent

able 4 illustrates the variations in treatment efficiency of the WSP for two years for the highest and lowest removal efficiency of COD and BOD5. The BOD5 removal efficiency was between 74.03% and 84.88%, while the COD removal efficiency was between 24.47& and 84.38%. COD removal efficiency was highest (84.38%) in March 2020, and BOD5 removal efficiency was highest (84.88%) in January 2020. COD removal efficiency was lowest (24.47%) in July 2020, and BOD5 removal efficiency was lowest (74.03) in April 2020. Table 4 indicates that the performance of the anaerobic pond was significant.

Table 4.1 Removal efficiencies percentage (%) concerning of the COD and BOD_5 influent and effluent ponds between January 2020 and July 2021

Date	COD (Mg/L)		Removal efficiencies (%)	BOD_5 (Mg/L)		Removal efficiencies (%)
	Inf.	Eff.		Inf.	Eff.	
12/01/2020	560	200	64.28	536	81	84.88
17/03/2020	1473	230	84.38	450	84	81.33
21/04/2020	792	207	73.86	362	94	74.03
02/07/2020	568	429	24.47	242	60	75.06
12/01/2021	657	334	49.16	447	88	80.31
03/07/2021	757	175	76.88	450	84	81.33

4.0 Conclusions

The final effluent can then be used for irrigation of the green belt in Hodeida city. Furthermore, it is expected that wastewater can be recycled for irrigation purposes after the expansion of the treatment plant, as long as social and religious barriers are overcome. As shown in Table 3, wastewater treated by waste stabilization ponds performs quite significant. To achieve a high-quality effluent that meets and complies with WHO guidelines, this is essential. It is recommended that tertiary treatment is performed using a waste stabilization pond to address this issue and produce water that meets national and international standards.

ACKNOWLEDGMENTS

The corresponding author especially thanks the fellowship from Institute of International Education- Scholar Rescue Fund (IIE-SRF). In particular, we thank Mr. Yahya Mutaher, head of the laboratories department at the Hodeidah station for sharing some data and providing assistance.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that they have no conficts of interest.

Acknowledgments

This work was conducted during our work at Hodeidah University.

How to Cite : Abdulbari A. Ahmad et al. (2023). Wastewater treatment plant assessment and potential reuse: A case study in Hodeidah (Yemen), *Abhath Journal of Basic and Applied Sciences*, 2(1), 29-33.

References

[1] **Aklan MM, de Fraiture C, Hayde LG.(2019).** Which water sources do people revert to in times of war? Evidence from the Sanaâ€™a Basin, Yemen. International Journal of Environmental Research; 13: 623-638.

[2] **Ghulam M, Alshamaâ€™a MH. (2016)**, Adapting a resilience improvement programme in conflict: experiences from Yemen. Field Exchange 53: 47.

[3] **Al-Gheethi AA, Abdul-Monem M, Al-Zubeiry A, Efaq A, Shamar A, Al-Amery RM. (2014),**Effectiveness of selected wastewater treatment plants in Yemen for reduction of faecal indicators and pathogenic bacteria in secondary effluents and sludge. Water Practice and Technology; 9: 293-306.

[4] **UNICEF. Children dying daily because of unsafe water supplies and poor sanitation and hygiene, UNICEF says. Press Release, New York**: **(2003).** UNICEF (22 March). Available at http://www. unicef. org/media/media_68359. html.

[5] **HOOD. (2011).** Alternative Report Submitted to the Committee on Economic, Social and Cultural Rights in the Context of the Review of the Second Periodic Report of Yemen. In: National Organization for Defending Rights and Freedoms Yemen;.

[6] **Zabara B, Ahmad AA. Biomass waste in Yemen: 2020**Management and challenges. In: Waste Management in MENA Regions: Springer;: 313-336.

[7] **Alraggad M, Ahmad AA.(2021).**Impact and assessment of As-Samra wastewater treatment plant on the water quality of the Zarqa River: A review..

[8] **Carr R, Blumenthal U, Mara D. (2004).** Health guidelines for the use of wastewater in agriculture: developing realistic guidelines. Wastewater use in irrigated agriculture: Confronting the livelihood and environmental realities: 41-58.

[9] **Division USEPAOoWMMS, Transfer NRMRLT, Division S. (2004).** Guidelines for water reuse. US Environmental Protection Agency;.

[10] **Rice EW, Baird RB, Eaton AD, Clesceri LS. 2012**Standard methods for the examination of water and wastewater. American public health association Washington, DC;.

[11] **Maiga A, Konate Y, Wethe J, Denyigba K, Zoungrana D, Togola L. (2006).** Performances Ã©puratoires dâ€™une filiÃ¨re de trois Ã©tages de bassins de lagunage Ã microphytes sous climat sahÃ©lien: cas de la station de traitement des eaux usÃ©es de lâ€™EIER..

[12] R**ejsek F. Analyse des eaux: Aspects rÃ©glementaires et techniques. (2002).**Centre rÃ©gional de documentation pÃ©dagogique d'Aquitaine;.

[13] A**yers RS, Westcot DW. (1985).**Water quality for agriculture. Food and Agriculture Organization of the United Nations Rome;.

[14] **Curtis TP, Mara DD, Silva SA.(1992)** Influence of pH, oxygen, and humic substances on ability of sunlight to damage fecal coliforms in waste stabilization pond water. Applied and environmental microbiology; 58: 1335-1343.

[15] **Tadesse I, Green F, Puhakka J. (2004).**Seasonal and diurnal variations of temperature, pH and dissolved oxygen in advanced integrated wastewater pond systemÂ® treating tannery effluent. Water research; 38: 645-654.

[16] **Mara D. 1997**Design manual for waste stabilisation ponds in India. Lagoon Technology International Leeds;.

[17] **Ratchford I, Fallowfield H**.(**2003).** The effect of light: dark cycles of medium frequency on photosynthesis by Chlorella vulgaris and the implications for waste stabilisation pond design and performance. Water science and technology; 48: 69-74.

[18] **Mara D. (2000).** The production of microbiologically safe effluents for wastewater reuse in the Middle East and North Africa. Water, Air, and Soil Pollution; 123: 595-603.

[19] A**lcalde L, Oron G, Gillerman L, Salgot M, Manor Y. (2003) .**Removal of fecal coliforms, somatic coliphages and F-specific bacteriophages in a stabilization pond and reservoir system in arid regions. Water Science and Technology: Water Supply; 3: 177-184.

[20] **Almas A, Scholz M. (2006) .**Potential for wastewater reuse in irrigation: case study from Aden (Yemen). International journal of environmental studies; 63: 131-142.

[21] **WHO A. (1987)**. Wastewater stabilization ponds: principles of planning and practice..

[22] **Nelson KL, Cisneros BJ, Tchobanoglous G, Darby JL. (2004) .** Sludge accumulation, characteristics, and pathogen inactivation in four primary waste stabilization ponds in central Mexico. Water research; 38: 111-127.