ISSN NO. 2320-5407

Journal homepage: http://www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH

RESEARCH ARTICLE

Performance evaluation of different wastewater treatment technologies

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Manuscript Info

Manuscript History:

Received: 18 January 2016
Final Accepted: 26 February 2016
Published Online: March 2016

Key words:
Wastewater treatment plant, BOD, COD, TSS, Biological treatment, Removal efficiency

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Abstract

The present study presents the evaluation of the performance efficiency of the wastewater treatment plants in El-Gharbia governorate in Egypt which hosts about 34 plants. These plants are designed and constructed to treat wastewater via removing organic matter, solids, nutrients, disease-causing organisms and other pollutants, before it reenters a non-fresh surface water bodies. In a preliminary study the performance efficiency of thirty different wastewater treatment plants (WWTPs) were evaluated. The investigated sewage treatment plants operating by biological treatment method comprising 5 different treatment technologies including conventional activated sludge, oxidation ditch, extended aeration, rotating biological contactors and aerated lagoons, with an average wastewater inflow of 10256.967 m^3/day. Wastewater samples were collected at different sites of the treatment plants and analyzed for the major water quality parameters, such as biochemical oxygen demand (BOD), chemical oxygen demand (COD) and total suspended solids (TSS). The removal efficiency of each plant for TSS and BOD was calculated. This removal efficiency reflects the overall performance efficiency of each plant. The preliminary study revealed that Kotour WWTP, which operate with oxidation ditch technology exhibit the highest performance efficiency, while Tanta stage 2 WWTP which operate with conventional activated sludge technology exhibit the lowest one. The obtained results and recommendations are very much useful in identification and rectification of operational and maintenance problems as well as the future expansion to be carried out in the plants to meet the increased hydraulic and organic loadings.

Introduction:-

We are silently but surely heading towards "water shock" which will dwarf any oil crisis, because in the last two decades for the first time in the human history more water is being taken out across the globe than what nature is putting in. Wastewater is used water, comprising of substances such as human waste, food scraps, oils, soaps, chemicals, domestic wastes. Businesses and industries also contribute their share of used water/wastewaters in addition to storm runoff burdened with harmful substances via run off from roads, parking lots and rooftops and this can harm our fresh water systems. Even though, nature has an amazing ability to cope with certain amounts of contaminants, there is a necessity to treat the billion gallons of wastewater and sewage generated daily by homes, industries, and business establishments before releasing it back to the environment.

In Venezuela, 97 percent of the country's sewage is being discharged raw into the environment (Anonymous, 1998) while, most of sub-Saharan Africa is without wastewater treatment. In a relatively developed Middle Eastern country such as Iran, totally untreated sewage has been injected into the Tehran city's groundwater (Tajrishy and Abrishamchi, 2005). As such urban drainage system should also be considered as an important infrastructure in removing both wastewater and rainwater from city to prevent unhygienic conditions and to avoid damage from flooding (Erbe et al., 2002).

Wastewater or sewage treatment is one such alternative, wherein many processes are designed and operated in order to mimic the natural treatment processes to reduce pollutant load to a level that nature can handle. In this regard, special attention is necessary to assess the environmental impacts of existing wastewater treatment facilities (Jamrah, 1999). A detailed characterization of the incoming wastewater and a performance evaluation was carried out for the domestic wastewater treatment plant of Erzincan City, Latin America (Nuhoglu et al., 2004), wherein 15% of collected wastewater passes through treatment plants (with varying levels of actual treatment). Evaluation of municipal wastewater treatment plants with different technologies at Las Rozas, Madrid, Spain (Colmenarejo et al., 2006) and characterization of the influent and the effluent wastewater for performance evaluation at Sivas, Turkey (Coskuner and Ozdemir, 2006) are some of the important contributions.

In view of the large performance variability observed in the systems investigated, it is more convenient to evaluate the performances efficiency of the wastewater treatment plants in the area of study in order to improve the poor performances. In this context the major water quality parameters which reflect the overall performance efficiency such as biochemical oxygen demand (BOD), chemical oxygen demand (COD) and total suspended solids (TSS) will determine.

Experimental:-

Performance evaluation

a. Study area

This study evaluates (analyses) the performance of five different wastewater treatment technologies (conventional activated sludge, oxidation ditch, extended aeration, rotating biological contactors and aerated lagoons) operating in El-Gharbia governorate in Egypt. The present study covered more than 88% of the wastewater treatment plants in El-Gharbia governorate, which contain about 34 wastewater treatment plants. These plants were designed and constructed in order to receive an average of 493500 cubic meters of raw sewage per day, while in 2013 they actually received up to 307709 cubic meters per day. These plants were also designed and constructed in order to treat wastewater to meets the standards for discharging into non fresh surface water according to law No. 48 of 1982 before it reenter non-fresh surface water bodies. The treatment of wastewater from different sources contributes to the reduction of the environmental pollution as well as to maintain the citizen's public health.

b. Influent and effluent analysis

Grab and composite wastewater samples were collected at influent and effluent of the investigated plants. For conventional physical, biochemical and chemical analysis, glass and polyethylene bottles were used, while polyethylene bottles were used for heavy metals analysis and sterilized polyethylene bottles were used for total coliforms (TCF) analysis. Composite samples were collected over 12 hours at a rate of one sample each one hour. In the grab samples immediately after sampling the residual chlorine (R. Cl_2), temperature (Temp.,) and pH were measured according to the standard methods for the examination of water and wastewater (APHA, 2011). Wastewater composite samples were analyzed for total suspended solids (TSS), biochemical oxygen demand after 5 days at 20 Ċ (BOD_5), chemical oxygen demand (COD), total dissolved solids (TDS), ammonia (NH_3), nitrate (NO_3), total nitrogen (TN), total alkalinity (TA), oil and grease (O & G), Sulphides, chlorides, total coliforms (TCF) and heavy metals total content including Zn, Mn, Cu, Pb, Co, Ni and Fe within 24 hours of sample collection using the methods described in the standard methods for the examination of water and wastewater (APHA, 2011). Wastewater treatment plants overall treatment efficiency for TSS, BOD_5, COD, TDS, NH_3, TN, TA, (O & G), sulphides, chlorides, TCF and heavy metals removal were calculated in addition to the influent COD/BOD_5 ratio.

c. Statistical analysis

Statistical presentation and analysis of the present study was conducted, using the mean, standard deviation and Student t-test [Unpaired], Paired t-test, Chi-square ANOVA by SPSSV17.

Results and Discussion:-

Assessment of wastewater treatment technologies in El-Gharbia governorate

Currently, there is around thirty four (34) wastewater treatment plants in El-Gharbia governorate, with total design capacity of approximately 509500 m^3/day, and total actual capacity of approximately 320409 m^3/day, these plants have different operational conditions and standards as they operate with different technologies such as conventional activated sludge, oxidation ditch, extended aeration, rotating biological contactors (RBC), aerated lagoons, bio towers, trickling filter and up flow anaerobic sludge blanket (UASB).

Table (1) presents the investigated wastewater treatment plants and the employed technologies in El-Gharbia governorate. The results indicate that the oxidation ditch technology is the most common followed by conventional activated sludge then extended aeration then rotating biological contactors (RBC) then bio towers then aerated lagoons, trickling filter and up flow anaerobic sludge blanket (UASB).

Table 1. The employed technologies of the wastewater treatment plants in El-Gharbia governorate.

Type of treatment (wastewater treatment technologies)	No. of wastewater treatment plants
Oxidation ditch	11
Conventional activated sludge	9
Extended aeration	6
Rotating Biological Contactors (RBC)	3
Bio towers	2
Aerated lagoons	1
Trickling filter	1
Up flow Anaerobic Sludge Blanket (UASB)	1
Total number of wastewater treatment plants	34

Performance efficiency of the investigated wastewater treatment technologies

a. TSS removal efficiency

Table (2) presents the mean TSS removal efficiency of the investigated wastewater treatment technologies in El-Gharbia governorate. The obtained data indicates that the mean TSS removal efficiency of the different technologies fall in the range from 17.9 % to 94.9 % which reflects the significant difference in the efficiency of the reported technologies. As well as the results of Table (2) demonstrate that the aerated lagoons efficiency is significantly the highest one while the efficiency of the conventional activated sludge technology is the lowest one. This may be attributed to the difference in the operational conditions and standards of the applied technologies.

Table 2. Mean TSS removal efficiency

Wastewater treatment technologies	Mean TSS removal efficiency						ANOVA	
	% Range			Mean	±	SD	F	P-value
Conventional activated sludge	17.9	-	94.5	76.7	±	17.6	19.628	<0.001*
Oxidation ditch	62.7	-	94.2	87.4	±	6.7		
Extended aeration	66.5	-	94.9	87.4	±	5.8		
Rotating biological contactors (RBC)	71.6	-	94.2	88.9	±	4.5		
Aerated lagoons	86.0	-	93.9	89.8	±	2.2		

All data represents means of 12 replicas per year ± Standard Deviation (SD); TSS: Total suspended solids.

b. BOD_5 removal efficiency

Table (3) illustrates the mean values of BOD_5 removal efficiency of the investigated wastewater treatment technologies in El-Gharbia governorate. These results show that the mean of BOD_5 removal efficiency of the different technologies lies in the range 21.9 % - 94.7 % which reflects the significant difference in the efficiency of these reported technologies. The data in Table (3) demonstrate that the BOD_5 removal efficiency of the aerated lagoons technology is significantly the highest one while the BOD_5 removal efficiency of the conventional activated sludge technology is the lowest one. This is could be due to the difference in the operational conditions and standards for each of these technologies.

Table 3. Mean BOD_5 removal efficiency

Wastewater treatment technologies	Mean BOD_5 removal efficiency						ANOVA	
	% Range			Mean	±	SD	F	P-value
Conventional activated sludge	21.9	-	93.3	75.9	±	17.6	19.315	<0.001*
Oxidation ditch	53.1	-	94.1	86.4	±	7.1		
Extended aeration	67.1	-	92.7	86.5	±	5.3		
Rotating biological contactors (RBC)	76.5	-	93.1	88.4	±	3.3		
Aerated lagoons	86.6	-	94.7	88.8	±	2.4		

All data represents means of 12 replicas per year ± Standard Deviation (SD); BOD_5: Biochemical oxygen demand after five days.

Influent COD/ BOD_5 ratio of the investigated wastewater treatment technologies

Table (4) presents the mean values of influent COD/BOD_5 ratio of the investigated wastewater treatment technologies in El-Gharbia governorate. The results show that the mean influent COD/BOD_5 ratio of the different technologies ranged from 1.11 to 2.77. These results show a non-significant difference in the mean influent COD/BOD_5 ratio for the different investigated wastewater treatment technologies. The present results illustrate that mean influent COD/BOD_5 values are comparable to those presented by Metcalf and Eddy (1991; 2003) who reported that the typical COD/BOD_5 ratio of domestic wastewater is usually in the range 1.25 to 2.5. This means that the influent wastewater are human wastes in nature and does not contaminated with industrial wastes which containing slowly biodegradable organic suspended solids or refractory substances for biodegradation or both of them. The influent COD/BOD_5 values of the investigated wastewater treatment technologies are lower than 3 which indicate that these influent wastewaters can usually be successfully treated with biological processes because of their high biodegradability. These results are in agreement with the data reported by Ng Wun Jern, (2006).

Table 4. Mean influent COD/BOD_5 ratios.

Wastewater treatment technologies	Mean influent COD/BOD_5 ratio						ANOVA	
	Range			Mean	±	SD	F	P-value
Conventional activated sludge	1.200	-	2.420	1.728	±	0.288	0.997	0.409
Oxidation ditch	1.110	-	2.770	1.786	±	0.290		
Extended aeration	1.270	-	2.470	1.792	±	0.291		
Rotating biological contactors (RBC)	1.200	-	2.500	1.724	±	0.288		
Aerated lagoons	1.410	-	2.090	1.719	±	0.270		

All data represents means of 12 replicas per year ± Standard Deviation (SD); BOD_5: Biochemical oxygen demand after five days; COD: Chemical oxygen demand.

Design, actual flow and the disposal point of each WWTP:-

An overview of the currently available operating wastewater treatment facilities in El-Gharbia governorate are shown in Table (5). The data reveal that the design flow capacity of the WWTPs in the studied area ranges 2000 to 90000 m^3/day and their actual flow capacity extend from 1500 to 70920 m^3/day. Table (5) shows that the actual incoming flow to all investigated WWTPs is equal to or less than the design flow and there is no WWTP exceeded the recommended maximum design flow. All WWTPs in the studied area discharges its treated wastewater (effluent) into the agricultural drain as shown in Table (5). The data in Table (6) shows that the design flow (16450.000 m^3/day) is significantly higher than the actual flow (10256.967 m^3/day).

Table 5. Overview of the investigated WWTPs in El-Gharbia governorate.

WWTPs	Treatment technology	Design flow (m^3/day)	Actual flow (m^3/day)	Discharge towards
Kotour	Oxidation ditch	10000	3500	A.D
Sonbat	Extended aeration	10000	4000	A.D
Shenrak	Oxidation ditch	2000	1500	A.D
Mahalet Marhom	Oxidation ditch	15000	12000	A.D
Zefta	Conventional activated sludge	20000	9000	A.D
Mahalet Menof	Aerated lagoons	12000	3000	A.D
Mahalet Zayad no.1	Oxidation ditch	2000	2000	A.D
Met Yazed and Elkorashia	Oxidation ditch	10000	3000	A.D
Shony	Rotating biological contactors	6000	2000	A.D
Elsanta	Conventional activated sludge	20000	12000	A.D
Fesha Sleem	Rotating biological contactors	3000	1800	A.D
Basyoun	Conventional activated sludge	20000	9000	A.D
Kafr Elzayat	Conventional activated sludge	78000	41089	A.D
Elgafaria	Extended aeration	7000	3000	A.D
Met Bader Halawa	Extended aeration	7000	2000	A.D
Berma	Oxidation ditch	10000	3000	A.D
Shershaba	Extended aeration	7000	3000	A.D
Mashal and Kom Elnagar	Extended aeration	2500	1800	A.D
Neshyl	Rotating biological contactors	3000	1500	A.D
Mahalet Zayad no.2	Oxidation ditch	15000	4000	A.D
Saft Trab and Elhyatem	Oxidation ditch	10000	6000	A.D
Segen Elcoom	Oxidation ditch	10000	3000	A.D
Samol and Dmtno	Oxidation ditch	10000	3000	A.D
Besh beesh	Oxidation ditch	10000	5200	A.D
El Moutamadia	Conventional activated sludge	4000	2000	A.D
Nawag	Extended aeration	3000	2400	A.D
Nefia	Conventional activated sludge	7000	3000	A.D
Elmahala Elcobra	Conventional activated sludge	90000	70920	A.D
Tanta stage 1	Conventional activated sludge	60000	60000	A.D
Tanta stage 2	Conventional activated sludge	30000	30000	A.D

A.D**:** Agricultural drain; WWTPs: Wastewater treatment plants.

Table 6. Design and actual flow of the investigated WWTPs in El-Gharbia governorate.

Incoming flow (m^3/day)	Range	Mean ± SD	Paired Differences		Paired Samples Test	
			Mean	SD	t	P-value
Actual flow	**1500.000 - 70920.000**	**10256.967 ± 17344.204**	**-6193.033**	**7201.385**	**-4.710**	**<0.001***
Design flow	**2000.000 - 90000.000**	**16450.000 ± 21535.196**				

The highest and the lowest efficiency WWTPs

The preliminary study included physical, biochemical and chemical measurements of raw untreated wastewater (influent) and treated wastewater (effluent) of thirty different WWTPs in El-Gharbia governorate performed for 12 months, indicates that Kotour WWTP exhibit the highest performance efficiency, while Tanta stage 2 WWTP exhibit the lowest one.

The data in (Table 7) shows that Kotour WWTP exhibit higher efficiency than Tanta stage 2 WWTP. Mean influent COD/ BOD_5 ratio of Kotour WWTP is insignificantly higher than that of Tanta stage 2 WWTP. Values of both of them were comparable to those presented by Metcalf and Eddy (1991; 2003) and those reported by Ng Wun Jern, (2006). There is no significant variation in the influent TSS, BOD_5 and COD of both investigated plants. This variation in performance efficiency of both plants is attributed to the difference in the operational conditions and mainly the difference in the efficiency of the treatment process. The observed lowering of the efficiency of Tanta stage 2 WWTP is due to the presence of some operational disorders in its operating system.

Table 7. TSS, BOD_5, COD, effluent $R.Cl_2$, TSS removal efficiency, BOD_5 removal efficiency and influent COD/BOD_5 ratio of Kotour and Tanta stage 2 WWTPs.

Variables		Wastewater treatment plants						T-Test	
		Tanta stage2 WWTP			Kotour WWTP				
		Mean	±	SD	Mean	±	SD	t	P-value
TSS	IN	304.000	±	49.448	293.167	±	55.409	0.505	0.618
	E	144.583	±	51.734	24.583	±	5.054	7.997	<0.001*
BOD_5	IN	390.000	±	48.006	372.083	±	61.882	0.792	0.437
	E	181.500	±	54.602	36.583	±	6.201	9.135	<0.001*
COD	IN	657.417	±	90.803	639.667	±	105.991	0.441	0.664
	E	238.500	±	67.249	60.667	±	8.510	9.088	<0.001*
Effluent $R.Cl_2$		0.000	±	0.000	1.242	±	1.315	-3.270	0.004*
TSS removal efficiency (%)		51.1	±	19.7	91.5	±	1.9	-7.078	<0.001*
BOD_5 removal efficiency (%)		52.3	±	16.7	90.1	±	1.5	-7.775	<0.001*
Influent COD/BOD_5 ratio		1.708	±	0.287	1.742	±	0.316	-0.277	0.784

All data represents means of 12 replicas per year ± Standard Deviation (SD); TSS: Total suspended solids; BOD_5: Biochemical oxygen demand after five days; COD: Chemical oxygen demand; IN: Influent; E: Effluent

Types of the incoming raw wastewater (human and industrial wastes):-

The influent COD/BOD_5 ratio of the investigated plants (Kotour and Tanta stage 2) was determined to clarify the nature of the incoming raw wastewater (human and industrial wastes). The typical COD/BOD_5 ratio of domestic waste waters is usually in the range 1.25 to 2.5 as reported by Metcalf and Eddy, (1991; 2003). The data in Table (8) illustrates the influent BOD_5, COD, and COD/BOD_5 ratio of Kotour and Tanta stage 2 WWTPs. The data indicates that the values of the influent COD/BOD_5 ratio for both investigated plants are comparable to those presented by Metcalf and Eddy (1991; 2003) and to those reported by Ng Wun Jern, (2006).

The results illustrate that the influent COD/BOD_5 ratio of Kotour and Tanta stage 2 WWTPs are within the normal range (1.25 to 2.5) as reported by Metcalf and Eddy (1991; 2003). This finding reveals that the incoming untreated raw wastewater (influent) of both investigated WWTPs are human wastes in nature and does not contaminated with industrial wastes which containing slowly biodegradable organic suspended solids or refractory substances for biodegradation or both of them. In this context, Eckenfelder, (1989) stated that there is usually no correlation between BOD_5 and COD in wastewater with slowly biodegradable organic suspended solids and in complex waste effluents containing refractory substances. Hence, treated effluents may exert virtually no BOD_5 and yet exhibit a substantial COD. Since, the COD represents virtually all organic matter, either while BOD_5 represents the biodegradable organic wastes. Accordingly it is necessary to develop relationship between BOD_5 and COD.

The data in Table (8) demonstrate that, the influent wastewater of Tanta stage 2 WWTP exhibit a mean BOD_5 (432.857 mg/L) significantly higher than that exhibited by the influent wastewater of Kotour WWTP (337.5 mg/L). Influent COD of Tanta stage 2 WWTP (687.571 mg/L) is insignificantly higher than that of the influent of Kotour WWTP (682.125 mg/L). Influent COD/BOD_5 ratio of Tanta stage 2 WWTP (1.628) is significantly lower than that of Kotour WWTP (2.040). The variability of BOD_5, COD and COD/BOD_5 ratio of the influent wastewater of Kotour and Tanta stage 2 WWTPs could be ascribed to the difference in the social and economic reasons in the area of both WWTPs. The observed decrease in the biological treatment performance efficiency of Tanta stage 2 WWTP as compared to Kotour WWTP is attributed to the detected increase of BOD_5 and COD of the influent of Tanta stage 2 WWTP in addition to its operational disorders.

Table 8. BOD_5, COD and COD/BOD_5 ratio of the influent of both Kotour and Tanta stage 2 WWTPs.

Investigated parameters	Kotour WWTP			Tanta stage 2 WWTP			T-test	
	Mean	±	SD	Mean	±	SD	t	P-value
BOD_5 (mg/L)	337.500	±	68.400	432.857	±	85.189	-2.405	0.032*
COD (mg/L)	682.125	±	123.337	687.571	±	55.698	-0.107	0.916
COD/BOD_5	2.040	±	0.205	1.628	±	0.251	3.498	0.004*

All data represents means of 8 replicas ± Standard Deviation (SD); BOD_5: Biochemical oxygen demand after five days; COD: Chemical oxygen demand; WWTP: Wastewater treatment plant.

Industrial establishments in the area of the evaluated plants:-

The results in Table (9) show that, in the area of Kotour WWTP which contains seven industrial establishments there is only one has effluent meets the standards for discharging into the sewerage system, while the others have effluents does not meet these standards. The observable highest performance efficiency of Kotour WWTP may is attributed to the fact that:

a. The decrease in the number of the industrial establishments in its area leads to decreasing the amount of the industrial wastewater discharged into the sewerage system.

b. These effluents pollutants are highly diluted in the sewerage system due to the mixing with the wastewater which contains about 99.1% to 99.5% water.

Based on the above arguments one can conclude that the highly diluted pollutants of the industrial establishments effluents have a weak effect on the treatment process efficiency of Kotour WWTP. On the other hand, in the area of Tanta stage 2 WWTP which contains sixty industrial establishments there are thirty six have effluents meet the standards for discharging into the sewerage system, while the others have effluents does not meet these standards. This observed poor performance efficiency of Tanta stage 2 WWTP can be attributed to some operational disorders in the operating system. Examination of the operating units of Tanta stage 2 WWTP reveal that these treatment operating units suffering from miserable operational disorders.

Table 9. An overview on the industrial establishments located in the area of Kotour and Tanta stage 2 WWTPs.

Studied areas		A		B		industrial establishments	
		Number	Percentage (%)	Number	Percentage (%)	Total number	Total percentage (%)
Kotour WWTP		6	85.71	1	14.29	7	100.00
Tanta stage 2 WWTP		24	40.00	36	60.0	60	100.00
Total		30	44.78	37	55.22	67	100.00
Chi-square	X^2	3.61					
	P-value	0.057					

A: industrial establishments which have effluents do not meet the standards for discharging into the sewerage system

B: industrial establishments which have effluents meet the standards for discharging into the sewerage system

Influent and effluent characteristics of Kotour and Tanta stage 2 WWTPs:-

The results in Table (10) reveal that Kotour WWTP TDS removal efficiency is higher than that of Tanta stage 2 WWTP. The influent TDS of Kotour WWTP is higher than that of Tanta stage 2 WWTP. According to the present results, Tanta stage 2 WWTP which operate with conventional activated sludge technology shows poor performance in terms of TSS, BOD_5, COD, NH_3, O & G, sulphides and total coliforms (TCF) compared to the reference range (maximum limit) reported in the literature (law 48 of 1982). On the other hand, Kotour WWTP which operates with oxidation ditch technology exhibits a better performance which meets the reference value.

The results in the Table (10) demonstrate that Tanta stage 2 WWTP exhibits removal efficiencies of the reported pollutants lower than Kotour WWTP. The residual chlorine value of the effluent of Tanta stage 2 WWTP (0.0 mg/L) does not meet the reference value, while the residual chlorine value of the effluent of Kotour WWTP (1.5 mg/L) is in agreement with the reference value (0.5 – 1.5 mg/L). Kotour WWTP is more efficient than Tanta stage 2 WWTP for removing of total alkalinity (TA) (18.18% and 12.96% respectively) and chlorides (38.46% and 9.43% respectively). The influent COD/BOD_5 ratio of Kotour and Tanta stage 2 WWTPs are within the normal range according to Metcalf and Eddy, (1991; 2003) and according to Ng Wun Jern, (2006). The effluents of Kotour and Tanta stage 2 WWTPs COD/BOD_5 ratios are higher than that of its influents. This observation is in accordance with the observation of Eckenfelder, (1989) who reported that the COD/ BOD_5 ratios frequently varied for effluents compared to untreated wastes.

The observed difference in the characteristics of the influent of both Kotour and Tanta stage 2 WWTPs may be attributed to social, geographic, climatic and economic conditions in their area. The difference in the nature and properties of the effluent of both WWTPs can be ascribed to the difference in the treatment efficiency of both WWTPs.

The discussion mentioned above, demonstrates that Kotour WWTP has significantly higher performance efficiency than that detected for Tanta stage 2 WWTP. This finding can be ascribed to the fact that, increasing of sulphides, oil and grease and ammonia concentrations in influent of Tanta stage 2 WWTP than that in the influent of Kotour WWTP. Further more some operational disorders in the operating system of Tanta stage 2 WWTP was observed.

Table 10. Influent and effluent characteristics of Kotour and Tanta stage 2 WWTPs.

Parameter	Units	Kotour WWTP		Tanta stage 2 WWTP		Maximum limit (mg/L)
		Influent	Effluent	Influent	Effluent	
Temperature	(Ċ)	27	28	26	26	35
pH		7.35	7.22	7.21	7.62	6-9
TDS	mg/l	1130	850	614	610	2000
TDS removal efficiency	%	24.77876		0.65146		
TSS	mg/l	365	25	312	118	50
TSS removal efficiency	%	93.15068		62.17948		
$BOD_{(5)}$	mg/l	380	33	380	190	60
$BOD_{(5)}$ removal efficiency	%	91.31578		50		
COD (Dichromate)	mg/l	680	65	544	310	80
COD removal efficiency	%	90.44117		43.0147		
COD/ $BOD_{(5)}$ ratio		1.7894736	1.9696969	1.4315789	1.6315789	
NH_3	mg/l	72	1.5	91.5	19.3	---
NH_3 removal efficiency	%	97.91666		78.9071		
NO_3	mg/l	0.8	29	0.7	4.2	
TN	mg/l	75	13.4	58.6	14.9	---
TN removal efficiency	%	82.13333		74.57337		
TA	mg/l	264	216	216	188	
TA removal efficiency	%	18.18181		12.96296		
Oil and Grease	mg/l	126	7.8	264	34.6	10
O & G removal efficiency	%	93.80952		86.89393		
Sulphides	mg/l	3.4	0.0	24.4	3.6	1
Sulphides removal efficiency	%	100		85.2459		
Chlorides	mg/l	520	320	265	240	
Chlorides removal efficiency	%	38.46153		9.43396		
Total coliforms (TCF)	CFU/100 ml	> 1600000	2100	> 1600000	> 1600000	5000
Total coliforms removal efficiency	%	99.86875		0.0		
Residual chlorine	mg/l	---	1.5	---	0.0	(0.5 – 1.5)

TDS: Total dissolved solids, TSS: Total suspended solids, BOD_5: Biochemical oxygen demand after five days, COD: Chemical oxygen demand, TN: Total Nitrogen, TA: Total Alkalinity and O & G: Oil and grease. The maximum limit (mg/L) for sewage effluent discharged into non-fresh surface water bodies are according to law 48 of 1982 which determine the standards and specifications of sewage and industrial liquid effluent which are licensed to discharge into brackish or saline surface water bodies (non-fresh surface water bodies). Law 48 of 1982 is aimed to protect the Nile River and its waterways from pollution.

Heavy metals content of the influent and effluent of Kotour and Tanta stage 2 WWTPs:-

Heavy metals such as Zn, Mn, Cu, Pb, Co, Ni and Fe were determined in the influent and effluent of both investigated WWTPs and the results obtained are listed in Table (11). The data in Table (11) demonstrate that the concentration of Zn, Mn, Cu, Pb and Fe in the effluent is lower than that detected in the influent in the case of Kotour WWTP. Similar trend is detected for Tanta stage 2 WWTP except for Mn content which present in the effluent with higher concentration than in the influent. These results reveal that the removal efficiency of heavy metals differed according to their types and WWTP performance efficiency. This recorded heavy metals removal is bacterial action in accordance with the previous similar studies (Johncy Rani et al. 2010; Leusch et al. 1995; Holan and Volesky, 1994; Rani and Haripriya, 2003; Gulay et al., 2003; Yi-Tin and Changsong, 1995 and Salehizadesh; Shojaosadati, 2003).

Table 11. Heavy metals content of the influent and effluent of Kotour and Tanta stage 2 WWTPs.

WWTPs	Heavy metal total content	Zn	Mn	Cu	Pb	Co	Ni	Fe
units		mg/L	mg/ L	mg/ L	mg/ L	mg/ L	mg/ L	mg/ L
Kotour WWTP	Influent	0.2	0.2125	0.031	0.0115	0.0	ND	1.8125
	Effluent	0.1125	0.109	0.008	ND	0.0	ND	0.1875
	Removal efficiency (%)	43.75	48.70588	74.19354	-----	------	-----	89.65517
Tanta stage 2 WWTP	Influent	0.1625	0.275	0.0345	0.0305	0.0	ND	1.15
	Effluent	0.0875	0.2875	0.014	0.007	0.0	ND	0.6625
	Removal efficiency (%)	46.15384	-----	59.42028	77.04918	-----	------	42.3913

ND: None detected (Under the detection limit); WWTP: Wastewater treatment plant

Conclusion:-

The difference in the nature and properties of the raw wastewaters (influents) may be attributed to social, geographic, climatic and economic conditions in the different areas, while the difference in the characteristics of the treated wastewaters (effluents) mainly ascribed to the difference in the treatment efficiency of the different WWTPs. Highly diluted industrial effluents weakly affected the performance efficiency of WWTPs. The aerated lagoons technology is the most efficient in the removal of TSS and BOD_5. Wastewater treatment plant operated with oxidation ditch technology is more stable and efficient than that operated with conventional activated sludge technology.

Recommendations:-

In order to improve the wastewater treatment plants performance efficiency the following recommendations should be considered.

1. Avoid the poor conditions of sewerage system, the discharge of untreated trade (industrial) effluents and the improper design of the plant and organizational problems.
2. During start-up or after WWTP breakdown, adding specialized microorganisms or activated sludge from another WWTP will improve the efficiency. This operational tool is called "bio-augmentation".
3. Fresh sludge with higher microorganism populations should be recycled and the aerators must be operated continuously to maintain good dissolved oxygen in the system and providing mixing that promotes the formation of good flock particles that will settle readily in the clarifier.
4. Avoid the overloading due to increase in population and water use.
5. Keep the wastes in the treatment process longer in the case of high organic loading to provide a longer time for treatment. The use of oxidants, such as chlorine, may provide short-term help for an organically overloaded plant. However, the organic loading should be checked with the design parameters for the plant. If the actual organic loading is higher than the design loading, expanding the plant capacity is the only long-term solution.
6. Industrial wastewaters often have organic strengths much higher than those encountered in sewage. Such strong wastewater may benefit from anaerobic pretreatment ahead of the aerobic treatment stage so that organic strength can be reduced and hence reducing the aeration and the consequential energy requirements.
7. Frequent and accurate sampling and laboratory analysis one of the important tools leading to WWTPs improvement.
8. Some knowledge of the manufacturing process can be helpful in understanding industrial wastewater characteristics which can help the designer and operator anticipate the surges in terms of timing, volume, and strength.
9. Industrial wastewater treatment plants (IWTPs) should frequently include equalization tanks in their treatment trains. These serve to produce flows, or compositions, or both which are closer to the average values used in the IWTP designs.
10. It is, therefore, important that operators understand the different types of solids and be able to determine the quantities of each type. This knowledge of solids, coupled with collecting the appropriate data, provide information operators need to effectively operate and control wastewater treatment systems.
11. To achieve good settling conditions in gravity clarifiers, the surface overflows rates chosen for design and operation of a clarifier usually range from 0.3 to 0.7mms^{-1}.

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