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Performance Evaluation of Wastewater Treatment Plants in El-Fayoum

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Abstract

The present study has been undertaken to evaluate performance efficiency of wastewater treatment plants (WWTPs) in El-Fayoum Markaz, El-Fayoum governorate in Egypt. The wastewater treatment plants using different treatment techniques were Active sludge, Oxidation ponds, Secondary - active sludge and Chemical (nanotechnology) which wastewater samples were collected from both influent and effluent of each plant. The key performance of each plant is estimated based on the treated wastewater quality data. Based on the results, they showed that Old Quhafa (Secondary - active sludge technology) operates with removal efficiencies higher than 80% for biological oxygen demand (BOD), chemical oxygen demand (COD) and total suspended solids (TSS) were established. While Ezbet Ashour accomplished lowest performance efficiency that operates with chemical-nanotechnology. This analysis applied to define a performance measuring plan based on the most important parameters that can be reliable and applicable for any WWTP. The study suggested formula for performance WWTPs that described by the expressing removal efficiencies as relative values or percentages and the remaining fraction. The study recommended that sedimentation units must be cleaned, monitoring frequently of sludge analysis and calculation of building capacity for all WWTPs.

Keywords: Wastewater treatment; Plants; El-Fayoum Governorate

Introduction

Civilization and culture with good drain reflects high-quality sanitation and beautiful statue for community. Water supply and their variety of uses led to receive wastewater with range of potential chemical polluting, microbial flora that acquires hazard health and environmental **(Shalinee and Ademola, 2014)**. Uncontrolled disposal of wastewater causes communicable diseases, water borne infectious so sanitary wastewater disposal protecte public health **(Lagarde et al., 2003)**.

Sewage effluents are major sources of organic pollution that have negative environment impacts. Therefore, prevention of pollution for natural resources (land and water) by non treated wastewater and adequate preparation or renovation of the wastewater before reuse, are further important considerations in formulating and designing appropriate wastewater disposal arrangements **(Joshua et al., 2017)**.

Characteristics of raw wastewater and treated wastewater are important requirements of disposal or reuse. The degree of treatment based on the effluent standards approved by the regulatory agencies to be discharged into a watercourse or land. Sequential combination of various physical unit operations, chemical and biological unit processes may be required for high quality of effluent to support, indicate the degree of treatment necessary water reuse **(Muzammil, 2016)**.

Treatment process included reduction of Suspended Solids (SS), Biological oxygen demand (BOD) and chemical oxygen demand (COD) which is key parameters of performance evaluation of wastewater treatment plant (WWTPs) and constitutes organic pollution. Moreover, the performance efficiency of treatment plant depends not only on proper design and construction but also on good operation and maintenance **(Hreiz et al., 2015)**.

Performance evaluation of WWTPs is necessary (1) to assess effluent quality, meet higher treatment requirements, ability of WWTPs to handle higher hydraulic and organic loadings. Performance appraisal practice of WWTPs is effective in generation of additional data which can be used for design procedures improvement by process modifications (significant expansion and/or modification of existing facilities) **(Guven et al., 2019)**.

A major tool required for proper process control is frequent, accurate sampling and laboratory analysis **(APHA, 2017)**. In the current wastewater treatment process, microorganisms play a significant role in the treatment of domestic sewage. Many different organisms live within the wastewater itself, assisting in the breakdown of certain organic pollutants **(Jafarinejad, 2017)**.

Increasing population, water use and overloading discharge of trade effluents are other reasons of recent times may cause reduced performance of wastewater treatment plants **(EEA, 2016)**. Therefore, WWTPs system, unacceptable design of the plant and organizational problems are important factors that decrease WWTPs performance and their efficiency to meet standards requirements (Tušer and Oulehlová, 2021). The present study aims to evaluate the wastewater treatment plants effectiveness in capital Fayoum city, El-Fayoum Governorate.

Methodology

Case of Study

The Fayoum Governorate with a population of 2.48 million (January 2005 census) and Fayoum City as the principal town is occupying a natural closed depression in the Western Desert of Egypt between 29°020 and 29°350N and 30°230 and 31°050E. It extends over 6068 km^2 and is situated about 95 km southwest of Cairo **(Fig.1)**.

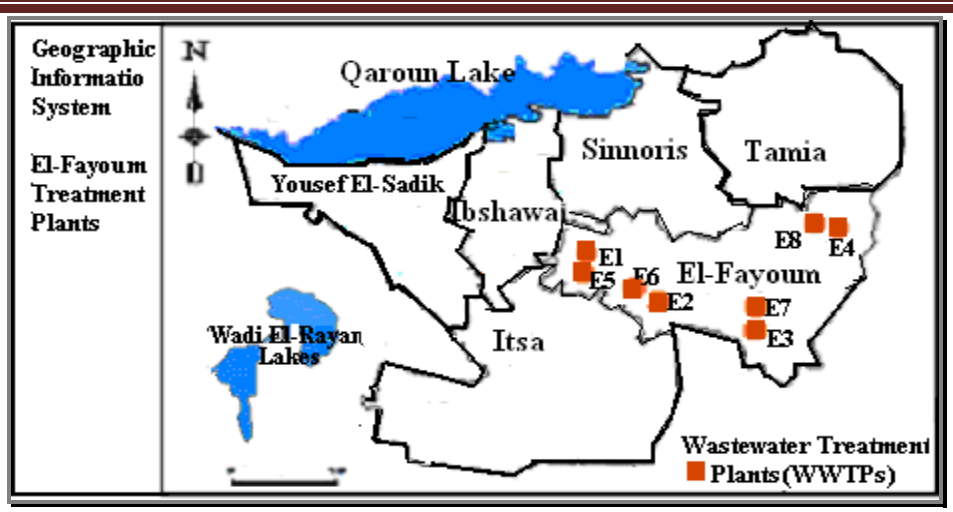


Fig 1. Locations site of different WWTPs along Fayoum Governorate

Sampling

Four monitoring locations for wastewater treatment plants namely: Zayoet Kerdsa, El-lauon, Old Quhafa and Ezbet Ashour along capital Fayoum city, El-Fayoum Governorate are chosen for examination. Water samples that four inlets of WWTPs samples and four outlets of WWTPs) are collected during 2018-2019 as shown in **Table I.**

Table 1. Descriptive of Locations for (WWTPs) in capital Fayoum City, El-Fauoum Governorate

No.	WWTPs	Drain	Treatment Technology	Sample Code	
				Inlet	Outlet
1	Zayoet Kerdsa		P_1-Active sludge (a)	E1	E5
2	El-lauon	Nakhla	P_2-Oxidation ponds (b)	E2	E6
3	Old Quhafa	Hana	P_3-Secondary - active sludge (c)	E3	E7
4	Ezbet Ashour		P_4-Chemical (nanotechnology) (d)	E4	E8

The methodology developed to study the performance of the WWTP is divided into the following steps:

- Identification and characterization of flows associated to the operation of WWTP
- Pollutants – Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD)

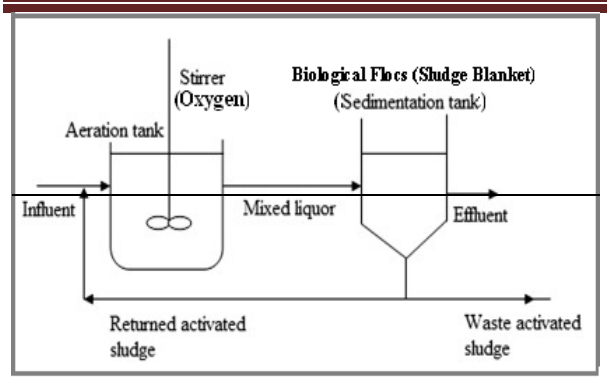
Consideration Analyze

The composite samples are analyzed for various parameters included physical, chemical and biological (BOD_5 and COD) according **APHA (2017)**. Data analysis carried out using COD/BOD_5 ratio to improve treatment plants control and operation.

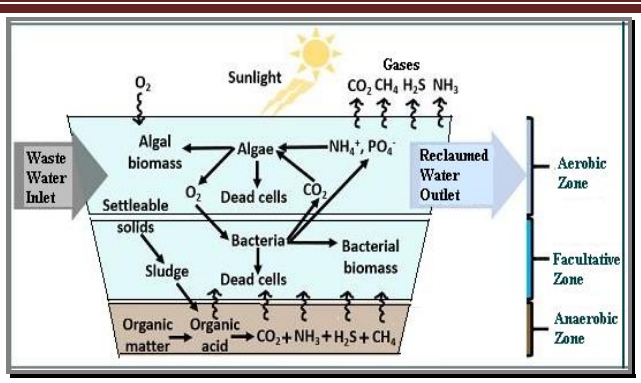
Results

System description of wastewater treatment plants (WWTPs)

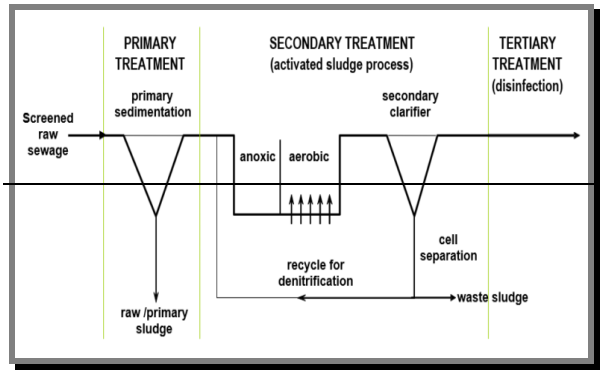
The systems of wastewater treatment plants using different treatment techniques are described as following: (a) active sludge, (b) oxidation ponds, (c) Secondary–active sludge and (d) Chemical (nanotechnology) in Fig. (2):



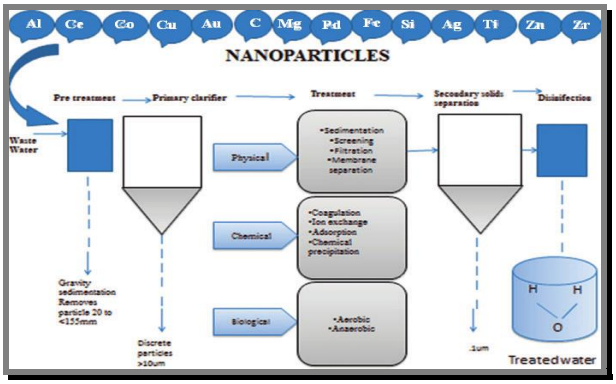
(a) Active Sludge and Processes



(b) Oxidation Pond and Processes



© Secondary - active sludge



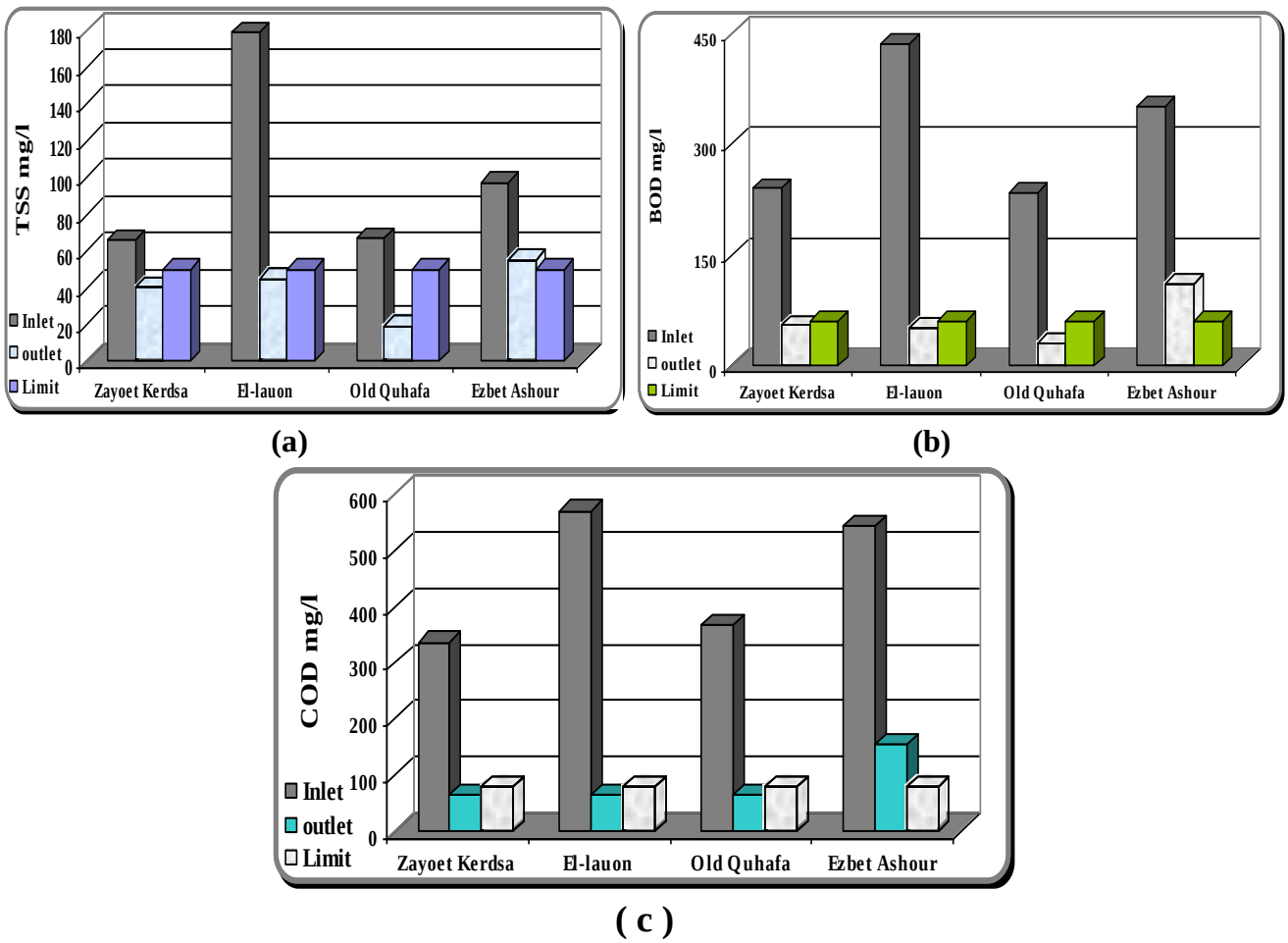
(d) Chemical (nanotechnology)

Fig. 2. Schematic Diagram of Different Treatment Techniques: (a) Active Sludge and Processes, (b) Oxidation Pond and Processes, © Secondary - active sludge, (d) Chemical (nanotechnology)

Performance analysis measurements (TSS, BOD_5 and COD)

Figure 3a showed that the concentration mean value of TSS is 102 mg/l for inlet WWTPs wastewater (the values ranged from 66 to 179 mg/l). The concentration mean value of BOD is 315 mg/l for inlet WWTPs wastewater (the values ranged from 234 to 436 mg/l) for inlet wastewater as shown in Fig.3b. While the concentration mean value of COD is 454 mg/l for inlet WWTPs wastewater (the values ranged from 336 to 569 mg/l) as shown in Fig.3c.

On other hand, **Fig.3 (a, b and c)** described the variation trend of TSS, COD and BOD_5 for average concentrations of WWTPs outlet. The concentration mean value of TSS is 40 mg/l, (the values ranged from 19 to 45 mg/l) that less than 50 mg/l except Ezbet Ashour (55mg/l) as shown in **Fig. 3a**.



Figs. 3. Variation Trend of TSS, BOD_5 and COD for WWTPs (Inlet and outlet) along Fayoum city

The concentration mean value of BOD (outlet WWTPs along Fayoum city) is 62 mg/l, (the values ranged from 30 to 55 mg/l) that less than 60 mg/l for WWTPS except Ezbet Ashour (110 mg/l) as shown in **Fig. 3b**. While the concentration mean value of COD is 87 mg/l, (the values ranged from 64 to 65 mg/l) for WWTPs that within approved Egyptian standards (80mg/l) except Ezbet Ashour (154 mg/l) as demonstrated in **Fig. 3c.**

Performance of wastewater treatment plants (WWTPs)

The present results demonstrate wastewater treatment plants performance: for Zayoet Kerdsa (Active sludge), El-lauon (Oxidation ponds) and Old Quhafa (Secondary - active sludge) along capital Fayoum city, El-Fayoum Governorate. F**ig. 4** demonstrated Old Quhafa (Secondary - active sludge technology) achieved highest performance efficiency. While Ezbet Ashour accomplished lowest performance efficiency that operates with chemical-nanotechnolog

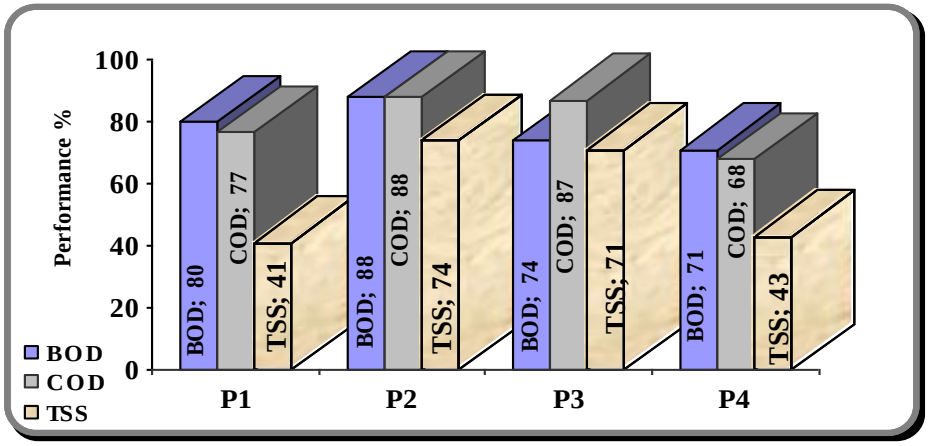


Fig. 4. Performance Trend of WWTPs in Terms of TSS, COD and BOD_5 along Fayoum City, El-Fayoum Governorate

Concept of removal efficiency

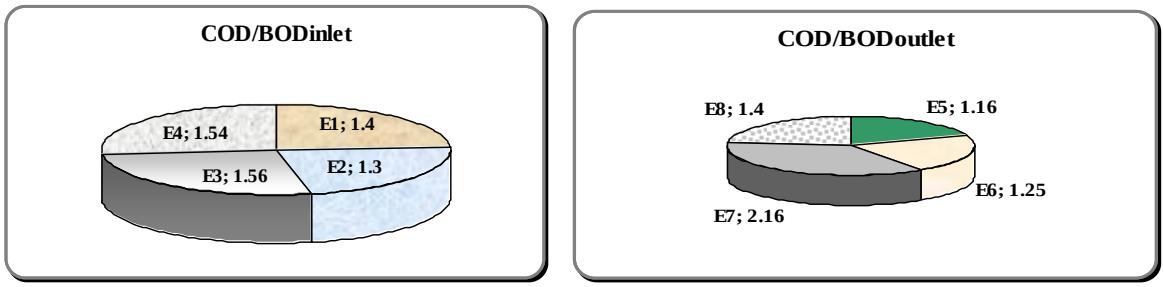
The data from influent and effluent sampling site are calculated for removal efficiency of pollutants to assess each wastewater treatment plant (WWTP) performance in report, and interpret removal efficiencies. The descriptive statistics (graphical methods) for removal efficiencies will be qualitative (categorized) data as those described in **Figures (3, 4 and 5)** column/bar chart and pie chart) for TSS, BOD and COD. There is some specificity in the calculation and interpretation of removal efficiencies will needed. Expressing removal efficiencies as relative values or percentages and the concept of the remaining fraction is listed in Table 2**.**

Table 2. Expressing removal efficiencies as relative values and percentages

Code	WWTP	Remaining Fraction			Relative Values (E)			Percentages (%)		
		TSS	BOD	COD	TSS	BOD	COD	TSS	BOD	COD
P1	Zayoet Kerdsa	0.59	0.20	0.23	0.41	0.80	0.77	41	80	77
P2	El-lauon	0.26	0.12	0.12	0.74	0.88	0.88	74	88	88
P3	Old Quhafa	0.29	0.26	0.13	0.71	0.74	0.87	71	74	87
P4	Ezbet Ashour	0.57	0.32	0.32	0.43	0.71	0.68	43	71	68

COD/BOD_5 Ratio

The values of investigated inlet WWTPs showed COD/BOD_5 ratio within the normal range (1.25-2.5) (**Salah etal., 2017)** that indicated WWTPs inlet were human wastes in nature as shown in Fig. 5a and b.



(a) **(b)**

Fig. 5. Organic ratio for inlet and outlet of WWTPs along Fayoum City, El-Fayoum Governorate

Discussion

The Performance of investigated WWTPs was in terms of outlet effluent quality that based on removal efficiency% of TSS, BOD_5, COD and influent COD/BOD_5 ratio during one year 2018-2019. Attention is focused on treatment technologies with the emphasis on biological processes that TSS, BOD_5 and COD are indirect indicators for total suspended solids, fermentable and non-fermentable organic content **(Slavov, 2017).** The obtained data for inlet WWTPs showed variation trend of TSS, COD and BOD_5 average concentrations for inlet WWTPs that attribute to different social, economic, geographic and climatic conditions in during investigated period. The data of TSS, COD and BOD_5 did not approve with Egyptian standards Law 48/1982 Decree 92/2013. The differences of BOD concentrations for outlet WWTPs attribute to qualify nature of organic loads, the type of the operational conditions and mainly the dissimilarity of efficiency treatment process with different technologies in the present study. The data of WWTPs performance agree with approval limits for Egyptian standards, Executive Regulation of Law 48/1982 Decree 92/2013 that protects fresh water courses from pollution by the discharged effluents except Ezbet Ashour (Chemical-nanotechnology). The data clarified secondary - active sludge that mass of microorganisms played key role of organic matter reduction for domestic, sewage and industrial wastewater **(Oliveira and Sperling, 2011)**. While Ezbet Ashour WWTP operates with chemical-nanotechnology design must be cleaned treatment units or used additional biological unit that high population micro-organism such as bacteria or algal cause chemical activity for COD reduction. This evolves understanding of technological advances and reduces costs for effluent quality **(Seyedeh et al., 2021)**.

Industrial wastes are characterized by low biodegradable organic suspended solids or refractory substances for biodegradation or both of them. While it can be observed COD/BOD_5 ratio for outlet are lower than 3 that indicated inlet wastewaters can usually be successfully treated with biological processes (high biodegradability) (Oliveira and Sperling, 2011). The suggested formula for performance WWTPs described by the expressing removal efficiencies as relative values or percentages in the following Equation (1-2).

$$E = \frac{\text{Input concentration} - \text{Output concentration}}{\text{Input concentration}} = \frac{\text{Removed concentration}}{\text{Input concentration}} = 1 - \frac{\text{Output concentration}}{\text{Input concentration}} \quad \textbf{Equation (1)}$$

$$E = \frac{C_{in} - C_{out}}{C_{in}} = 1 - \frac{C_{out}}{C_{in}}$$

$$= 1 - \text{Remaining fraction}$$

Express removal efficiencies as percentages, we simply multiply the value from Equation 1 by 100 and the concept of the remaining fraction, which is given by Equation 3:

$$E(\%) = \frac{C_{in} - C_{out}}{C_{in}} \times 100 = \left(1 - \frac{C_{out}}{C_{in}}\right) \times 100 \qquad \textbf{Equation (2)}$$

$$\text{Remaining fraction} = 1 - \text{Removed fraction} \quad \textbf{Or} = 1 - E = \frac{C_{out}}{C_{in}} \qquad \textbf{Equation (3)}$$

The overall percentage removal efficiency of the combined treatment units is based on the multiplication of the remaining fractions of the constituent in each unit.

$$E_{overall} = 1 - [(1 - E_1) \times (1 - E_2) \times \cdots \times (1 - E_n)] \qquad \textbf{Equation (4)}$$

or, expressing removal as percentages and the remaining fraction is the same:

$E_{Overall}$ (%) = 1 – [(1-E_1) X (1-E_2) X.....X (1-E_n)]

$$E_{overall}(\%) = 100 \times \left(1 - \left[\left(1 - \frac{E_1(\%)}{100}\right) \times \left(1 - \frac{E_2(\%)}{100}\right) \times \cdots \times \left(1 - \frac{E_n(\%)}{100}\right)\right]\right)$$

Conclusion and Recommendation

Four monitored wastewater treatment plants namely: Zayoet Kerdsa, El-lauon, Old Quhafa and Ezbet Ashour along capital Fayoum city, El-Fayoum Governorate are chosen for performance examination during one year. The water chemistry results exceeded Egyptian standards Law 48/1982 Decree 92/2013 limits for all inlet wastewater treatment plants (WWTPs) which reported their wastewater quality must be have suitable treatment. Therefore, the study assessed performance of wastewater treatment plants (WWTPs) and evaluated their consideration analysis (COD, BOD and COD/BOD_5).

The results reported had differences attribute to qualify nature of organic loads, the type of the operational conditions and mainly the dissimilarity of efficiency treatment process with different technologies in the present study. The research clarified that Old Quhafa (Secondary - active sludge technology) achieved highest performance efficiency. While Ezbet Ashour accomplished lowest performance efficiency that operates with chemical-nanotechnology. COD/BOD_5 ratio of investigated wastewater treatment plants (WWTPs) inlet were within normal range (1.25-2.5) and recorded <3 for wastewater treatment plants (WWTPs) outlet. So, these records indicated inlet wastewater were human wastes in nature and can usually be successfully treated with biological processes (high biodegradability).The study recommended that

- Sedimentation units must be cleaned,
- Monitoring frequently of sludge analysis and
- Calculation of building capacity for all WWTPs.

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