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Future Performance Study of Al-Muamirah Wastewater Treatment Plant Applying a Statistical Analysis

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ABSTRACT
Wastewater management is considered to be a great challenge, particularly in towns and cities with rapidly growing population. The study aimed to assess the Al-Muamirah WW treatment plant (WWTP), located in the Babylon governorate of Iraq, in terms of its hydraulic loading as a quality performance indicator. The findings showed that there will be a significant deficit in the capacity of the plant of 20%, 32% and 37% in the year of 2024, and will cumulatively arise in 2030 to become 26%, 41.5% and 47.7% for suggested growth rates of 1.27%, 2.5% and 3.95%, respectively. The outcomes of expected amounts of daily discarded wastewater in terms of estimated population were analyzed using the ANOVA test and it was found that the population growth ratio has a significant impact on the generated inflow, as $f(2,30) = 3.713$, and $p= 0.019 < 0.05$.

Keywords: future performance, statistical analysis, wastewater treatment plant

INTRODUCTION

Global warming threat, sharply accelerated population growth and evolution in the age of speed have aggravated depletion of water and subsequent overloading on WWTP. In addition to these environmental problems, freshwater availability is considered to be one of the major problems facing the world, and about one-third of drinking water requirement of the world is obtained from surface sources like rivers, lakes, dams and canals (Jonnalagadda and Mhere, 2001). Serious water crises, for instance water scarcity and pollution, have been a barrier to the future socio-economic developments (Teklehaimanot et al. 2015), due to lack of proper governance of land utilization and other uncontrolled anthropogenic activities (Du et al. 2010).

This steady increase in the anthropogenic pressures on this natural resource is caused by a continuous human population growth, which is alarming and requires an urgent balance between WW discharge and protection of the receiving water bodies (Burian et al. 2010). Scaling up in population results in dis-efficiency in treatment plant work as well as subsequent contamination of water body. Sustainable Development Goals (SDGs) were launched by the United Nations in 2015 to stimulate actions in the areas of critical importance for both humanity and the environment (Cossio et al. 2018). Therefore, saving this valuable, natural and substantial resource lies in potentials of its sustainable recycling, on the other hand, serving the areas with sewerage networks or extending the existing ones in particular, lead to this overloading of the treatment plant (Gzar et al. 2020) and wastewater affects many environments including soil, which needs to be treated (Laith et al. 2021).

The study (Teklehaimanot et al. 2015) had reported that WW treatment facilities are subject to fluctuations in population size and other urban developments (institutional, commercial, industrial, etc.), which affect or define their performance, i.e. flow rate, sludge retention time, microbial population, nutrient availability, and chlorine contact time. Hence, in order to defeat these fluctuations, assessing the existing condition (demands of the area and population) is a key pre-step for a successful WWTP. Apart from one study was analyzing the current operation of the WWTP prospective capacity that was calculated based on the estimation of the amount of the inflowing municipal WW in the 20-year perspective (until the year 2036) (Garbowski et al. 2018).

Al-Tufaily (2003) studied the characteristics of three $WWTP_S$ in the middle Euphrates, and he found that the actual organic load and hydraulic load for biological treatment units, in all of $WWTP_S$, were higher than their design criteria in addition to the raised values of pollutants concentrations reaching the plant, which had exceeded the constraints established by American Environmental Protection Agency (EPA) (1981). Evaluation of future performance for $WWTP_S$ in Baghdad (capital of Iraq) was investigated (Al-Zuhairy 2008), and results indicated that there was a performance deficit in the Al-Rustumia treatment plant about 73% at Al-Rasafa side of Baghdad and 70% at Al-Karckh side.

The necessity of estimating wasted water amount per capita for instance 20 years in advance is a technical step to predict the deficit percent of plant performance if present and keep up running the plant efficiently within its capacity and other constraints. The current study aimed to assess the future performance of the Al-Muamirah treatment plant from the year 2010 until 2030, in terms of the predicted wastewater amount as a function of population growth. The statistical study of the data was achieved by performing the ANOVA test.

METHODOLOGY

Al-Muamirah station description

The methodology of study depended on field surveying of the plant through collecting the data from the plant and concerned directorates. The plant structure description gives factual vision about the extent of service the plant supply. Moreover, it evaluates current efficiency as well as estimates the capacity and reliability at the next years. This plant is located at about five kilometers to the south of Hillah city. It was launched in 1984 with a designed capacity of 12000 m^3/d to serve about 20 percent of the city population. The station is composed of the following units and parts (this information were taken from Babylon sewerage directorate in 2020:

- Screens for isolating floating materials of the influent.
- Uplifting station consists of four pumps, each of 60 kW supplied with screens for impurities retention.
- Grit chamber where the suspended solids are being settled.
- Collecting tank for saving the water effluent coming out of the grit chamber.
- Flow distribution basin.
- Par shall flume for effluent measurement.
- Aeration tank (46.5×70×3 m) for biological treatment. Every tank is assisted with six surface aerators on both sides and rotate at a rotational speed of 32 revolution per minute with a power of 37 kW.
- Secondary sedimentation tank with a diameter of 32 m and depth of 2 m.
- Collecting tank to collect the water that coming from the sedimentation.
- Disinfection unit from which the treated water is discharged into the river.

The amount of future discarded wastewater and the resulted deficit of the plant

In order to estimate the amount of discharged WW in the next years, the population estimation formula is needed, which is used to predict the population in the future time (Al-Hadithy 2000):

$$R = \left[\sqrt[t]{\frac{p_1}{p_o}} - 1 \right] \cdot 100$$

where: R – annual population growth ratio,
p_0 – population in the previous census,
p_1 – population in the subsequent census.

After computing the estimated population, it will be substituted in the following formula for the predicted amount that could be generated from corresponding population:

Total amount of wastewater = estimated population · daily amount of wastewater per capita

Moreover, the deficit in the WWTP efficiency for treating the wastewater, will be found as follows:

Deficit percent ratio in the capacity =
$= (X_1 - X_2) / X_1 \cdot 100$

where: X_1 – Total daily wastewater amount (m^3/d),
X_2 – Design capacity of the plant = 12000 m^3/d.

RESULTS AND DISCUSSION

Influence of population growth on discharged WW and deficit in WWTP

Amounts of wastewater discharged into the river for 20 years in advance with respect to population growth rate during this period of time are listed below in Table 1. The plant is serving only 20% humans of Hilla city in the governorate of Babylon, that is why the data of Table 1 concerns only this segment of society. The expansion in estimated population according to the suggested growth rates of 1.27%, 2.5% and 3.95% caused an increment of about 1500, 3000 and 4000 capita per 2 years, respectively. Results predict the amounts of wastewater dsicharged in 2030 as 16170, 20523 and 22958 m^3/d with growth ratios of 1.27%, 2.5% and 3.95% respectively.

Considering the data above, it is clear that starting with the year of 2010, the discharged WW exceeded the design capacity (12000 m^3/d) of the plant, starting to increase directly over time. Whilst the rapid human population growth may boost the development of water and sanitation infrastructure, the lack of effective water resource management strategies could have a negative impact on the design capacity of WW treatment facilities, reticulation infrastructures as well as quantity and quality of water resources (Volkman 2003). These results are well represented as plotted curves and it indicates that the greater the growth ratio the more wasted water is discarded, as illustrated in Figure 1.

As it was previously mentioned, continuously increasing human population will cause many operational problems to the plant, in addition to environmental ones, overloading of WW amounts produced by the estimated population that directly proportional to the latter. Figure 2 shows how much lack would be recorded in the plant process of treatment when the deficit became greater year by year.

It was found by Teklehaimanot et al. [2015] that under the performance of the existing $WWTP_S$ the rapid population growth in urban and semi-urban areas (hydraulic overloading of the WW treatment plants) as well as operational

Table 1. Expected wastewater amount and percent ratio of deficit on the basis of the estimated population

Year	R = 1.27%			R = 2.5%			R = 3.095%		
	Estimated population	Total WW amount (m^3/d)	Percent ratio of deficit (%)	Estimated population	Total WW amount (m^3/d)	Percent ratio of deficit (%)	Estimated population	Total WW amount (m^3/d)	Percent ratio of deficit (%)
2010	60000	12600	4.8	60000	12600	4.8	60000	12600	4.8
2012	61524	12920	7.1	63000	13230	9.3	63708	13378	10.3
2014	63086	13248	9.4	66150	13890	13.6	67645	14205	15.5
2016	64688	13584	11.7	69457	14586	17.7	71825	15083	20.4
2018	66331	13929	13.8	72929	15315	21.6	76264	16015	25.1
2020	68016	14283	16.0	76575	16081	25.4	80977	17005	29.4
2022	69744	14646	18.1	80404	16885	28.9	85981	18056	33.5
2024	71515	15018	20.1	84424	17729	32.3	91295	19172	37.4
2026	73231	15378	22.0	88645	18615	35.5	96937	20356	41.0
2028	75091	15800	24.0	93077	19546	38.6	102927	21615	44.5
2030	76998	16170	25.8	97731	20523	41.5	109287	22958	47.7

Figure 1. Ilustravive photos of Al-Muamirah treatment plant, Hilla city, Babylon governorate

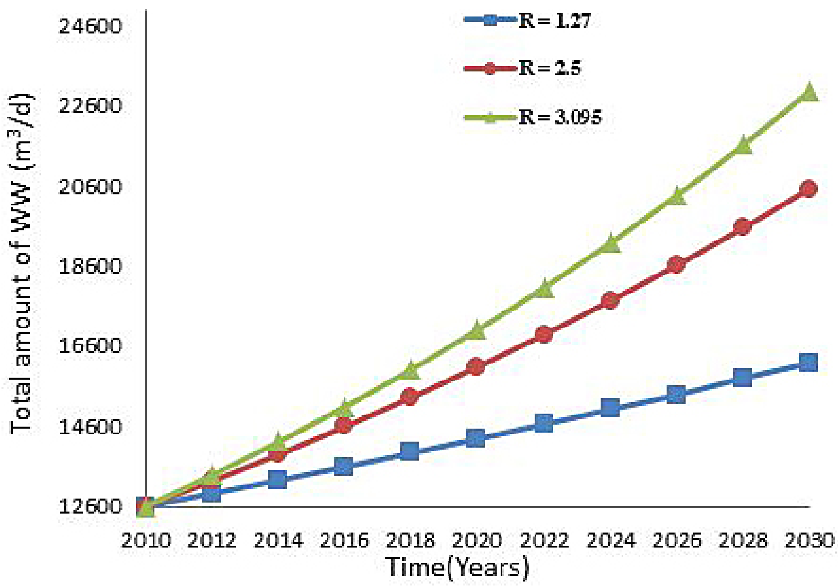

Figure 2. Predicted sewage water amounts of Hilla city, according to the estimated population

constraints resulted in the production of poor quality effluents in both selected areas. These outcomes are attributed to the fact that in developing countries, WW management countries interfere with complex challenges due to lack of technical expertise, weak management and institutional structures and a shortage of adequate policies to promote an integrated water management (Ujang and Buckley 2002).

ANOVA test results

A comparison between these outcomes will help to better understand exactly what is happening by subjecting the data to the analysis of variance test (ANOVA – Table 2) using the SPSS statistical program to infer if there is a significant difference in the mean of the three growth ratios. In order to determine which ratio causes the difference, Tukey HSD procedure is an appropriate technique to infer what ratio is different from the others and it was found that the ratio of 1.27% is significantly different than 3.95% but there is no significant difference for other comparisons, tabulated in Table 3, and this is logical to some extent because of the noticed difference between 1.27% and 3.95%.

Table 2. ANOVA test findings

Specification	Sum of Squares	df	Mean Square	F	Sig.
Between groups	49886993.152	2	24943496.576	3.713	0.036
Within groups	201519669.818	30	6717322.327		
Total	251406662.970	32			

Table 3. Multiple comparisons, Tukey HSD technique results

(I) pop	(J) pop	Mean difference (I-J)	Std. error	Sig.	95% Confidence interval	
					Lower bound	Upper bound
1	2	-1927.545	1105.139	.206	-4652.01	796.92
	3	-2967.818*	1105.139	.031	-5692.28	-243.35
2	1	1927.545	1105.139	.206	-796.92	4652.01
	3	-1040.273	1105.139	.619	-3764.74	1684.19
3	1	2967.818*	1105.139	.031	243.35	5692.28
	2	1040.273	1105.139	.619	-1684.19	3764.74

* The mean difference is significant at the 0.05 level.

CONCLUSION

Deficiency in the performance of the plant was found and reported as an indicator for the lack of design capacity of the WW treatment plant of Al-Muamirah, which is nowadays experiencing a deficit that would reacg 20, 32 and 37% in the year of 2024, and will cumulatively arise in 2030 to become 26, 41.5 and 47.7% for the suggested growth rates of 1.27%, 2.5% and 3.95%, respectively. The ANOVA findings showed that the population growth ratio has a significant impact on the generated inflow, as $f_{(2.30)} = 3.713$, and $p = 0.019 < 0.05$. The station units are subject to ageing, which is another reason causes increasing disefficiency of the treatment plant. Supporting and extra units could be built as an effort to improve the city's sanitation.

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