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Evaluating the efficiency of municipal wastewater treatment plant in AL-Dhibaei, Iraq

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ABSTRACT

In this study, municipal wastewater treatment plant (WWTP) in AL-Dhibaei, Tikrit, Iraq was monitored over a period of one year. The data of raw sewage, which enter WWTP and treated sewage were obtained and investigated. To assess the operational performance of WWTP, the necessary pollutant indicators including biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), and dissolved phosphorus (PO_4), were examined. The treatment plant reliability factor (RF) was determined in order to indicate an individual pollutant in the effluent sewage according to the permissible concentrations identified by the Iraqi Ministry of Health and Environment. RF values for BOD, COD, and PO_4 were 0.56, 0.82, and 0.4, respectively, which indicated proper performance since RF values below 1. In addition, the removal efficiency for (BOD, COD, and PO_4), exceeded the minimum required reduction; 43.75, 18.25, and 60.5, respectively. In addition, the stability of mixed liquor volatile suspended solids (MLVSS) to mixed liquor suspended solids (MLSS) ratio was determined and its variation was in the range of 0.5٦5-1.225, indicating a proper performance. The sludge volume index (SVI) values were below 50 mg L^{-1} and its range (5.68 – 27.27 mg L^{-1}), which was associated with efficient treatment interpretations at most of the time.

Keywords: Al-Dhibaei, reliability factor, sewage indicator, Sludge Volume Index, and wastewater treatment plant.
Article type: Research Article.

INTRODUCTION

Wherever humans settle and use water they discharge wastewater. Wastewater is the collective term for all used water contaminated to the extent that, for most purposes, it cannot be used without treatment. Generally, wastewater is considered as a negative resource due to the fact that the main component of it is human waste. Accumulating amounts of wastewater become a hazard since the pollutants commonly pose environment and a health risk for human and animal life (Kvernberg 2012; Metcalf *et al.* 2014). When a river receives overloading of physical and chemical constituents associated with human activities, environmental risk is happened, while the health risk is mainly due to pathogenic organisms (Kvernberg 2012). According to World Health Organization (WHO) reports, over 80% of ill and infected people in the world are due to insufficient treatment of sewage and hence unsatisfactory amount of clean water (Ibrahim *et al.* 2014: Mahdavy & Hosseinpour 2016). Wastewater treatment plant (WWTP) has primary aim, i.e., protection of public health and the environmental systems from excess load of different constituents. WWTP should meet basic functions such as the proper removal of contaminants from the entering wastewater, the decreasing emissions of greenhouse gasses (GHG), the saving of energy, and the competency to apply the part of treated effluent wastewater for different uses such as the agriculture (Garbowski *et al.* 2018). Fulfilling the increasingly firm wastewater treatment demands, which must

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conform to environmental standards, using elderly WWTP is the most challenging perspective of wastewater treatment functions facing decision-makers in municipalities (Qasem 2011). Evaluating the performance efficiency of the WWTP is challenging duty, principally since the uncontrolled fluctuations in the composition of sewage, continuing flow into the WWTP throughout a year (Arnell 2016). The operation efficiency of WWTP could be evaluated either on the basis of physical/chemical sewage indicators or using assessment models and perspective increase in population and proper design of WWTP infrastructure. Qasem (2011) assessed some of Canadian WWTP and the outcomes revealed that physical constituents retrograde WWTP infrastructures and integer program approach is used to optimize the improvement arbitration for each infrastructure unit. The operation efficiency of WWTP in Kłodzko City, Poland, was analyzed by Garbowski *et al.* 2018) based on the percent diminishment of individual five essential pollutants: BOD, COD, TSS, total nitrogen and total phosphorus. Their results revealed that performance of WWTP is quite enough to provide water protection in the receiving river. Al-Zahiri (2015) analyzed the present state of WWTPs in Jordan according to considering inflow and outflow rates, outflow quality, and treatment efficiency.

The present study aimed to assess the performance of the WWTP in AL-Dhibaei, based on the collected averaged data respecting the composition of the influent and effluent sewages for averaged monthly values (one year-period). The methodology of study depended on assessing treatment performance (WWTP). This regime can enable decision-makers to recognize rehabilitation needs for WWTP and to spot the main causes of ill performance.

MATERILAS AND METHODS

Characteristics of WWTP

Al-Dhibaei WWTP is located in Al-Dhibaei region, southwest of Tikrit City, Iraq. This WWTP is using a conventional activated sludge system as extended aeration system in aeration part before discharging the treated effluent into the river. Assessment of WWTP performance is a monitoring tool which is evaluated based on historical data averaged monthly values and aggregated to key performance indicators that are followed over time (Arnell 2016). The process of treatment is determined by various interconnected factors connected in complicated ways. Nonetheless, key indicators of the hygiene of the treatment process performance can be featured. This study employed two such indicators: sludge volume index (SVI) and mixed liquor volatile suspended solids (MLVSS). SVI images the robustness of biological treatment and indicates generable problems cohort with this type of treatment, such as presence of filamentous bacteria, buckling and rising of sludge (Garbowski, *et al.* 2018). The SVI value indicates settling impact of suspended solids (Table 1).

ABBREVIATIONS

BOD	Biochemical oxygen demand
COD	Chemical oxygen demand
DO	Dissolved oxygen
F/M	Food to microorganisms ratio
GHG	Green house gases
MLSS	Mixed liquor suspended solids
MLVSS	Mixed liquor volatile suspended solids
pH	Hydrogen-ion concentration
RF	Reliability factor
SVI	Sludge volume index
TSS	Total suspended solids
WHO	World Health Organization
WWTP	Wastewater Treatment Plant

Table 1. SVI and its treatment interpretations (Zhang *et al*. 2006).

SVI value (mg L^{-1})	Possible impact
SVI < 50	No impact (excellent)
50 < SVI < 100	Acceptable (check nutrients)
100 < SVI < 150	Filament growth
150 < SVI < 200	Sludge buckling at high flows
200 < SVI < 300	Sludge buckling
SVI > 300	Severe Buckling

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MLVSS controls the required F/M ratio and provides WWTP operators the stretchy to control production, storage and disposal of biomass. In addition, this study provides the value of the treatment plant reliability factor (*RF*) which was estimated by the ratio of the averaged concentration of a pollutant in the effluent sewage and its permissible value in the wastewater discarded to the receiving river, as illustrated in **Eq. 1**(Młyński *et al.* 2016):

$$RF = \frac{\bar{X}}{X_{per.}} \quad \ldots\ldots \textbf{ Eq. 1}$$

where $\bar{X}$: the average concentration of a pollutant indicator in the treated sewage as mg L^{-1}.
$X_{per.}$: the permissible concentration of a pollutant indicator in the treated sewage as mg L^{-1}.
When a value of *RF* is less than 1.0, verifies the right operation process of WWTP (Garbowski *et al*., 2018). The components of the municipal wastewater can be classified into physical, chemical and biological components which are in various ways connected and are significant in the subject of treatment process performance assessment (Kvernberg 2012).

RESULTS AND DISCUSSION

At First, in order to fulfill the two requirements for the character of effluent sewage: the maximum concentration of the pollutant indicator and the minimum level of reduction for the incoming effluent, the permissible values of the individual pollutant indicators and the required minimum reduction rates based on the effluent wastewater permit are shown in Table 2. The minimum required percentage reduction is calculated using Eq. 2:

$$Red.(\%) = \frac{X_{per.} - \bar{X}}{X_{per.}} * 100\ \% \quad \ldots\ldots \textbf{ Eq. 2}$$

Table 2. The required parameters of the treated sewage in accordance with the wastewater permit issued for Al-Dhibaei WWTP.

The quality indicator in sewage	The permissible concentration in treated sewage, $X_{per.}$ (mg L^{-1})*	The minimum percentage reduction, *Red.* (%)
BOD	40	43.75
COD	100	18.25
Dissolved PO_4	3	60.5

* The values of permissible concentration in treated sewage for pollutants are according to the Iraqi Health and Environment Ministry standards.

As shown in Table 2, the minimum percentage reduction for some of pollutants are not be evaluated, since the value of averaged concentration of a pollutant indicator in the effluent sewage exceeds its permissible concentration, and this is obvious in the estimation of RF values (Table 3). The RF value below 1.0 verifies the proper performance of WWTP, and vice versa. When RF values exceed 1.0, this means the performance of WWTP is inefficient and ill.

Table 3. The values of the treatment plant reliability factor (RF) for the treated sewage indicators

The quality indicator in sewage	The average value, $\bar{X}$ (mg L^{-1})	The permissible concentration in treated sewage, $X_{per.}$ (mg L^{-1})	The treatment plant reliability factor (*RF*)
BOD	22.5	40	0.56
COD	81.75	100	0.82
Dissolved PO_4	1.186	3	0.40

The SVI average values were below 50 mg L^{-1} (range = 5.68 - 27.27; Fig. 1). The SVI value below 150 mg L^{-1} is associated with efficient treatment interpretations (no impact; Table 1**)**.
Fig. 2 depicts the $\frac{MLVSS}{MLSS}$ average values for aeration basins at WWTP. The ratio of active sludge in total sludge ($\frac{MLVSS}{MLSS}$) exhibited variation in the range of 0.565-1.225 indicating a proper performance. The high ratio of $\frac{MLVSS}{MLSS}$ in activated sludge system may cause bulking, while the low values of this ratio indicate the microorganisms were not truly active (Sadeghpoor *et al.* 2009).

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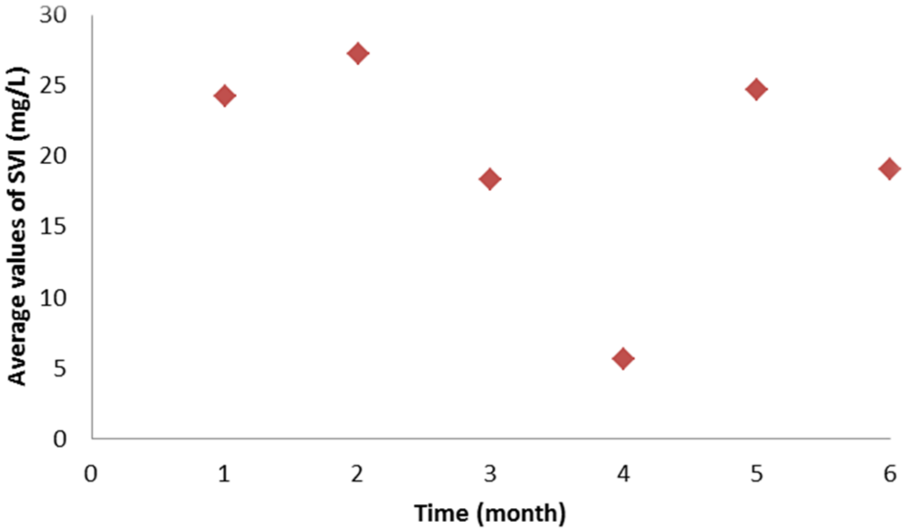

Fig. 1. The SVI average values for the duration of 6 months.

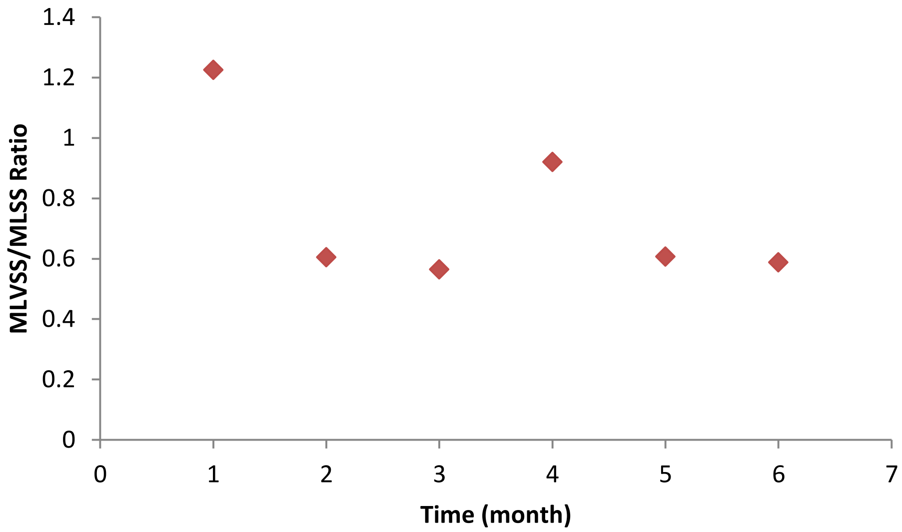

Fig. 2. The stability of the $\frac{MLVSS}{MLSS}$ ratio.

In the case of temperature indicator, wastewater has a higher temperature than the local water supply, as a result of a high content of warm water from households. In the present study, the mean temperature values varied with the local air temperatures (Fig. 3). The optimum temperature for biological treatment is in the range of 25 - 35 °C. In lower temperatures, the microbial reactions will appear more slowly, while at very high temperatures, aerobic digestion and nitrification stop (Kvernberg 2012).

Another indicator is pH which refers to the negative logarithm of the hydrogen ion concentration. The hydrogen ion concentration is of great concern in relation to biological treatment, because most microbial life occurs within a narrow pH range (typically 6-9; Kvernberg 2012). Fig. 4 depicts the inflow and outflow values of pH, which was stable to some extent, since the municipal wastewaters, unlike the industrial ones display slight fluctuations in the hydrogen-ion concentration.

Finally, the percentage removal of wastewater pollutant is calculated using Eq. 3:

$$R\,(\%) = \frac{C_{in} - C_{out}}{C_{in}} * 100(\%) \quad ......\textbf{Eq. 3}$$

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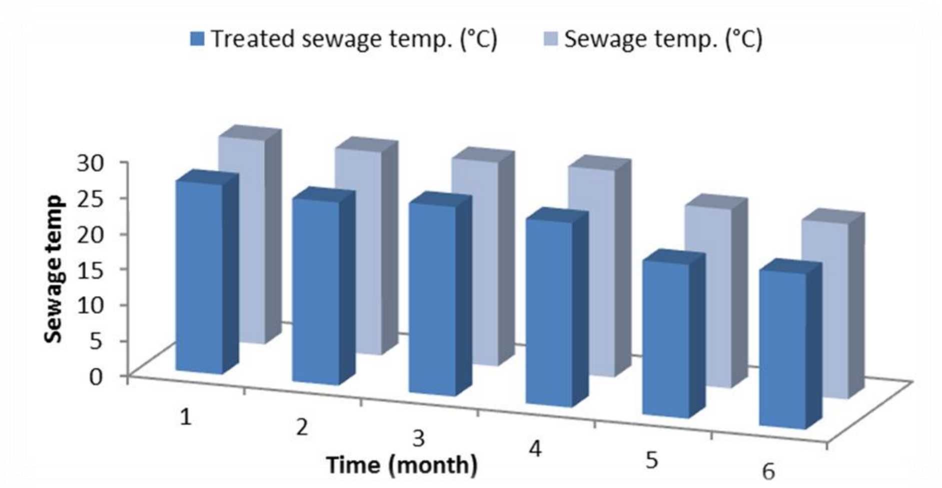

Fig. 3. The average temperature values in inflow and treated sewages.

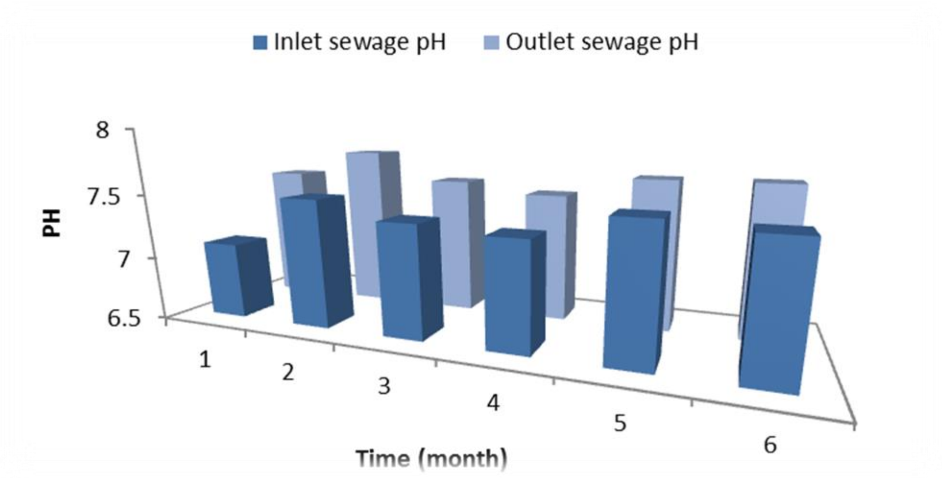

Fig. 4. The average pH values in inflow and treated sewages.

where R (%): Removal of wastewater pollutant (%)
C_{in}: the inflow concentration of pollutant (mg L^{-1})
C_{out}: the outlet concentration of pollutant, (mg L^{-1})
The results are depicted in Table 4. The values of removal percentage are the averaged ones for a collection data-period. The results revealed that the removal efficiency for BOD, COD, and dissolved PO_4 were reached the minimum required reduction rate (%) according to the permissible values of pollutant concentration by WHO. This indicated that the WWTP is proper-functioning according to these indicators. Typically, most of operators accept TSS removal efficiency of 60% to 70% because these sediments can be removed in other treatment phases. So, percentage removal of TSS (76.7%) at WWTP is acceptable.

Table 4. The removal rate (%) of wastewater pollutant at Al-Dhibaei WWTP.

Pollutants	Removal rate, R (%)	The minimum reduction rate, *Red.* (%)
Alkalinity	28.2	____
TSS	76.7	____
Salts	2.88	____
NH_3	37.3	____
NO_3	86.97	____
NO_2	33	____
BOD	79.8	43.75
COD	75.75	18.25
Dissolved PO_4	68	60.5

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CONCLUSION

Protecting health and natural waters are still the primary objectives of wastewater treatment. In light of what had been reached, it can be found that the current operation of Al-Dhibaei WWTP is suboptimal-functioning. Since the removal efficiencies reached the minimum required reduction for essential wastewater indicators including BOD, COD and PO_4 with removal efficiency of 79.8, 75.75, and 68 %, respectively. Furthermore, based on the permissible concentrations of the some pollutant indicators of sewage, the treatment plant reliability factor (*RF*) was estimated and its value below 1.0 indicates the right operation of the wastewater treatment plant; (RF_{BOD} = 0.56, RF_{COD} = 0.82, and RF_{PO4} = 0.4). In addition, the stability of Mixed Liquor Volatile Suspended Solids (MLVSS) to Mixed Liquor Suspended Solids (MLSS) ratio was determined and its variation in the range of (0.565-1.225), which indicates a proper performance. The Sludge Volume Index (SVI) values below 50 mg L^{-1} and its range (5.68 – 27.27 mg L^{-1}) which was associated with proper treatment interpretations at most of the time. For maintaining and thereby high efficiency of wastewater treatment, Al-Dhibaei WWTP should be modernized in the future. This will lead to operation of treatment process under optimal conditions.

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