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Performance Evaluation of Conventional Water Treatment Plants Using Turbidity and Disinfection Parameters

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ABSTRACT

Conventional water treatment plants (WTPs) typically involve two primary processes: turbidity removal and disinfection. This study evaluates the turbidity removal efficiency and the effectiveness of chlorination using daily records collected over one year from two WTPs, Dokan-1 and Dokan-2, located in the Sulaymaniyah Governorate, Kurdistan Region of Iraq.

Results of the study indicate mean turbidity removal efficiencies of 23.8% for Dokan-1 and 37.4% for Dokan-2. Although these values appear low, the performance of both plants is considered acceptable, as the 95th percentile of influent water turbidity during the study year was 9.46 NTU. The findings suggest that high turbidity removal efficiency is not expected when raw water turbidity is below 10 NTU. Therefore, assessing efficiency without considering influent turbidity is not a reliable approach. Throughout the study year of 2023, the average effluent turbidity values remained below the permissible limit of 5 NTU, with Dokan-1 and Dokan-2 recording averages of 3.27 NTU and 2.95 NTU, respectively. A one-sample t-test confirmed that effluent turbidity from both plants was significantly below the 5 NTU threshold. Turbidity removal efficiency can be calculated using two methods: (1) the mean of daily efficiencies which is the average of daily efficiencies, and (2) the efficiency based on average influent and effluent turbidity values. This study recommends the second method for evaluating conventional WTPs. Additionally, disinfection was successful in both plants, with average daily free chlorine concentrations of 1.41 mg/L for Dokan-1 and 2.26 mg/L for Dokan-2.

1.Introduction

Water is the essential factor for all forms of life on earth. According to the United Nation's Sustainable Development Goals (SDGs), specifically the SDG-6, access to clean and safe drinking water is considered as basic human right. From this perspective, especially in urban areas, water supply systems are recognized. Water treatment plant (WTP) removes contaminants from raw water, to produce safe water that poses no short-term and long-term risks to consumers' health. To safeguard the quality of the treated water from WTPs, effective monitoring and efficiency evaluation required. Since the early 20th century, conventional water treatment plants launched which involve coagulation, sedimentation, filtration and disinfection processes (Davis, 2010, Katila et al., 2019, Von Sperling et al., 2020). However, recently, traditional treatment method cannot remove new contaminants traced from industrialization activities such as organic and non-organic micro-pollutants from water. Therefore, advanced treatment units, such as reverse osmosis and nanofiltration, should be integrated into public water treatment plants (Sudhakaran et al., 2013).

There are two main types of water sources for treatment plants, groundwater and surface water. Turbidity is the most critical factor affecting surface water quality, while dissolved solids is the key parameter for assessing groundwater quality. For instance, turbidity as the most important and critical parameter used to assess the performance of Al-Karkh water treatment plant in Baghdad, Iraq which uses surface water from Tigris river (Janna and Al-Samawi, 2014). Reducing prevalence of water born disease and environmental management are counted as the greatest challenges in developing countries, which have low quality water with low efficiency water treatment (Ibrahim et al., 2014). (Ali et al., 2015) found that majority of the treatment plants in Pakistan have operation issues which results in low quality treated water. Performance of Dohuk water treatment plant evaluated using statistical techniques and results suggested that 97% of time the treated water is suitable for human consumption (Hassan, 2017). (Choudhury and Saha, 2018) suggested an index-based evaluation techniques as a multi-criteria decision making to evaluate the performance and efficiency of treatment plants. Khan and Ahmad (2018) reported that both turbidity and biological parameters of effluent water of water treatment plants were out of the allowable range in Nangloi in west Delhi, India. Multi-criteria decision analysis can be employed as superior criteria to evaluate operating and monitoring of treatment plants (Nawaz and Ali, 2018). Positive correlation detected between high turbidity events and increased acute gastroenteritis rate infections which make turbidity the more significant parameter of water quality to be controlled during water purification process (Setty et al., 2018). Assessment of a water treatment plant in Karbala city, Iraq showed a turbidity removal efficiency of 60.7%, organic removal efficiency of 82% and 52% in winter and spring seasons respectively (Ali et al., 2019). A study in Indonesia confirmed that some parameters of water quality exceeded the allowable range, however in general most of the time the quality of treated water was acceptable (Ayu et al., 2019). Removal efficiency of Ifraz-2 water treatment plant units in Erbil City, Iraq found to be 91.51 %, 64.71 %, and 97.29 %, for sedimentation, filtration and the entire plant respectively (Omar and Aziz, 2021). Effluent of a Water treatment plant analyzed using water quality index and health risk assessment in Turkey (Alver, 2019). Urban water security index calculated for water supply systems of Islamabad, Pakistan by some distinct parameters, namely existence of water, affordability and the quality of drinking water in the city (Khan et al., 2020). (Aziz and Omar, 2019) evaluated Qandil water treatment plant in Erbil, Iraq through calculating the water quality index of the treated water using turbidity, EC, total alkalinity, and total hardness parameters. (Nasier and Abdulrazzaq, 2022) assigned turbidity as the most critical parameter for surface water quality and used the turbidity to evaluate the removal efficiency of AL-Muthanna WTP, Iraq. Performance of Al-Rasheed water treatment plant in Baghdad, Iraq was assessed through evaluation of removal efficiency of the treatment plant (Mohammad et al., 2023). Acceptable performance efficiencies were obtained during studying of two treatment plants that supply Agra city in India through different water quality parameters (Rasooly and Anwer, 2023). Water treatment facility found to be ineffective in removal of contaminants in Ecuador, where residual free chlorine was the main problem in the treated water (Mendez-Ruiz et al., 2023). Turbidity removal efficiencies were calculated in a study to assess the efficiency and performance of a water treatment plant in South Africa (Bwapwa et al., 2024). Consistent monitoring program can improve the performance of a drinking water treatment (Mesfun and Derib, 2024). The previous literature review in the context of assessing the efficiency of conventional WTPs emphasizes the significance of turbidity and disinfection parameters. Accordingly, the objective of the current study is to evaluate efficiency of the two WTPs namely Dokan-1 and Dokan-2 plants, which supply several communities in Sulaymaniyah governorate with drinking water. The evaluation process includes the determination of turbidity removal efficiency and residual chlorine assessment.

2. Materials and Methods

2.1. Site Description

Sulaymaniyah governorate located in Kurdistan region of Iraq. The city governorate mainly supplied with drinking water from Dokan-1 and Dokan-2 treatment plants which are located in Peer Qurban (N 35.88808° and E 44.99651°) is about 65km northwest of Sulaymaniyah city. Both treatment plants receive water from Lesser Zab River downstream of Dokan Lake. The older one, Dokan-1 treatment plant has capacity of 3200 m^3/h, and the Dokan-2 treatment plant has capacity of 8000-12000 m^3/h. Dokan-1 treatment plant operative during hot seasons (about 5 months during a year), otherwise it is shut down. The two treatment plants supply water to most of the cities and towns in the governorate, namely, Sulaymaniyah, Piramagroon, Tasluja, Bazyan, Tainal, Gopala, Takiya, Chamchamal and Shorsh cites with an intermittent distribution plan. Both plants use conventional treatment processes which usually depend on coagulation, sedimentation, filtration and disinfection processes (Sulaymaniyah Water Directorate, 2013, Hamaamin and Abdullah, 2020).

2.2. Conventional Water Treatment Process

Raw water may contain pollutants which affect consumers' health, in the treatment plant all these types of contaminants shall be removed in order to provide suitable water for human consumption according to four water quality criteria (physical, chemical, biological and radiological). Typically, conventional treatment plants consist of the following units: intakes, flash mixer, flocculating, sedimentation, filter, disinfection and ground storage tank. Each unit has its own task in the treatment process. Intake delivers water from surface water sources, river or lake, to the treatment plant. The first unit that accept water from the intake is the flash mixer units, in which the coagulant matter, e.g. aluminum sulfate (alum), $Al_2(SO_4)_3$, added into the raw water usually rapid mixing applied to obtain a homogeneous solution. The coagulant function is to collect suspended particles in reasonable amount of time. Then water flows into the flocculating unit where a slow mixing applied to form flocks of suspended particles and coagulant matter. Water flows from the flocculation zone to sedimentation zone slowly, then the formed flocks will settle to the bottom of the tank, this process is usually done in clarifier units. Water flows from clarifiers to filters to remove any remaining or unremoved suspended particles. A filter bed usually consists of at least two layers of charcoal granules (anthracite) and a sand layer, here any escaped suspended particles will be trapped in the sand bed. After filtration the treated water should have turbidity according to specification (WHO specification for turbidity is <5 NTU). After filtration a disinfectant (usually chlorine) is added to the water to remove or kill all microorganisms especially pathogens which cause waterborne diseases (Davis, 2010, Von Sperling et al., 2020).

2.3. Turbidity Removal Efficiency

Turbidity is the cloudiness of water which is caused by existence of suspended or colloidal particles such clay, organic and inorganic matters. Turbidity assessment is an optical test of water clarity through testing transmission of light through the water sample. The common way to measure turbidity is Nephelometric Method, which measures turbidity by comparing the intensity of light scattered by a water sample with the intensity of light scattered by a standard reference suspension under the same conditions. Nephelometric Turbidity Units (NTU) is the unit measurement of the turbidity as well (Rice et al., 2017). Turbidity removal efficiency of a treatment plant measured by comparing the turbidity values at the influent and at the effluent, as shown in equation 1(Von Sperling et al., 2020).

$$efficiency = \frac{C_{in} - C_{out}}{C_{in}} \times 100 \qquad (1)$$

Where C_{in} and C_{out} are concentrations of suspended solid particles (turbidity) for the influent and effluent waters respectively.

Low turbidity removal efficiency indicates ineffective removal, and negative efficiency means that the effluent turbidity value higher than the influent value. According to water quality standards, the specified target value of turbidity is lower than 5 NTU value. While it is not easy to obtain reasonable removal of turbidity for influent turbidity values below 10 NTU with conventional treatment plants. Therefore, to evaluate the removal efficiency of a WTP, the only factor is not the efficiency value or sign, the efficiency must be evaluated together side by side with the effluent concentration and the allowable target value (Von Sperling et al., 2020).

2.4. Mean of Efficiencies and Mean Efficiency

The mean of efficiency or central tendency of the removal efficiency is the most important criterion to evaluate the function and duty of a WTP. Statistically the central tendency represents the most common values that can represent the majority of the given data; therefore, mean is the expected value of the data set at the center of the data distribution with the highest frequency. Moreover, a data set with normal distribution, mean can represent the central value, while for a data set with skewed or non-normal distribution, the median can describe the central tendency better compared to mean (Ott and Longnecker, 2016). In this regard we can calculate mean of efficiency in two different approaches, the first method (mean of efficiencies) is average of daily efficiencies, calculated from daily influent and effluent concentrations for the study period, as shown in equation 2. Usually mean of efficiencies are highly influenced by fluctuations of the daily data points values. In the second method, mean efficiency is calculated only one time based on the mean of influent and effluent concentrations, in other words, the mean of daily influent and effluent concentrations calculated and then use these two mean values to calculate the mean efficiency only once, as in equation 3.

$$mean\ of\ efficiencies = \frac{\sum_{i=1}^{n} daily\ efficiency}{n}$$

(2)

$$mean\ efficiency = \frac{\left(\frac{\sum_{i=1}^{n} C_{in}}{n}\right) - \left(\frac{\sum_{i=1}^{n} C_{out}}{n}\right)}{\left(\frac{\sum_{i=1}^{n} C_{in}}{n}\right)}$$

(3)

Where C_{in} and C_{out} are the influent and effluent concentrations and n is the number of daily records of turbidity in the study period.

The criteria for selecting one of the two means (mean of efficiencies or mean efficiency) to be considered for a treatment plant is the sample type. To evaluate water systems, there are two types of water samples, independent sample or dependent samples (paired samples). Generally, if the influent and effluent samples are independent samples, the mean efficiency should be used to represent the efficiency of the treatment plant. Otherwise, if the influent and effluent samples are dependent (paired) samples, the mean of efficiencies should be used (Von Sperling et al., 2020). Moreover, for most of flow-through conventional treatment plants, the mean efficiency is used because the influent and effluent samples are independent samples. Alternatively, mean of efficiencies can be used when samples are considered to be paired (dependent) samples, where the effluent samples are directly related to influent samples, for example systems contain sequencing batch reactors (Helsel et al., 2020, Von Sperling et al., 2020).

2.5. Disinfection

Disinfection is the process of removing pathogenic organisms from drinking water. Chlorine (Cl_2) is the most popular disinfectant in water treatment due to its reasonable cost and residual in the water. The chlorine reaction time in regular conditions is about 30 minutes to kill pathogenic organisms, this reaction is usually completed in a ground storage tank which is the last unit in WTP. Residual chlorine is the remained fresh chlorine which can stay for about 24 hours after disinfection to guarantee delivery of safe water to consumers. Whenever and wherever, in the water distribution pipe network, the residual chlorine falls outside the range of (0.2 mg/L < residual chlorine < 2 mg/L), the purity and safety of the water will be under concern (Davis, 2010). According to (WHO, 2022), for a successful disinfection, the turbidity should be kept below 5 NTU. While the bacteriological test of the treated water is not easy and time consuming, remained fresh chlorine (free chlorine) after at least 30 minutes from the process launch, would be a good indicator of no pathogens in the treated water. Therefore, to maintain the quality of the treated water, WTP effluent water should conserve free chlorine (residual chlorine) at a minimum concentration of about 0.2 mg/L to 0.5 mg/L. However, considering human health guidelines, the allowable maximum value of residual chlorine as a disinfectant in drinking water should not exceed 5 mg/L. However, the target value of free chlorine is 0.2 mg/L to 2 mg/L, because chlorine is a strong oxidizing agent reacting with many materials which result in unwanted contaminants in water (Davis, 2010, WHO, 2022).

2.6. Data Collection

Water quality data were collected from both treatment plants Dokan-1 and Doklan-2, for a period of one year, specifically January 1st, 2023 to December 31st, 2023. Influent Turbidity (raw water) and effluent from both treatment plants (Dokan-1 and Dokan-2), and daily water quality data recorded. In this study, for both treatment plants efficiency the collected data included, influent and effluent water turbidity in (NTU) units, and Free Chlorine (Cl_2) in (mg/L units). Table 1 shows descriptive statistics for the collected data, where central tendency through mean and median of the data provided for both WTPs. Also, in Table 1 dispersion of the data described by range and standard deviation of the data, finally the data distribution described by Skewness and Kurtosis.

Table 1: Collected data descriptive statistics .

Variable	N	Mean	Std. Dev	Min.	Median	Max.	Skewness	Kurtosis
Raw Water Turbidity	357	4.698	9.797	0.705	2.785	137.550	10.36	125.03
Dokan1-Tubidity	244	3.265	5.459	0.865	2.123	72.400	9.78	113.74
Dokan2-Turbidity	357	2.946	2.098	1.12	2.205	19.725	3.09	15.29

Dokan1-Free Chlorine	244	1.355	0.3888	0.20	1.400	3.00	-0.21	1.41
Dokan2-Free Chlorine	357	1.631	0.4000	0.00	1.650	3.00	-0.72	2.26

3. Results and Discussion

In this study water quality test results for the year of 2023 used from the two WTPs. A total 0f 357 daily data points for the Dokan-2 WTP are used, whereas a total of 244 daily data points for the Dokan-1 WTP are used. While the main task of conventional treatment plants is the removal of turbidity and then adding chlorine to disinfect it, in this study turbidity data points were collected at the influent (raw water) and the effluent locations of the two treatment plants (after filter units). Also, the efficiency of the two treatment plants evaluated through the two main parameters of water quality namely turbidity and free chlorine measurements. Existence of free chlorine is a sign of potability of treated water in terms of biological aspects of drinking water. For the two treatment plants, samples of treated water from the ground storage tank were tested for the free residual chlorine. Usually, the ground storage tank is the last unit in treatment plants which collects the treatment plant product of water, and provides the chlorine sufficient reaction amount of time to kill pathogenic organisms.

3.1. Turbidity Evaluation

Turbidity tests were performed on a daily basis of the two units' operation during the study period of one year. Table 2 shows characteristics of the turbidity collected data set for raw water (influent) at the intake which feeds both treatment plants at the same time, and the effluent of both treatment plants at the ground storage tanks. While the intake is located at a controlled section on the Lesser Zab River, downstream of the Dokan Dam, the river sediment load is relatively low. Consequently, from Table 2, one can observe that the turbidity of the raw water mostly at a reasonable level (95% of time the daily turbidity records is 9.46 NTU) which is less than 10 NTU. From Figure 1, number of days the raw water turbidity exceeding the 5 NTU limit is 96 days out of 357 operation days (or 261 days the turbidity of raw water was below the 5 NTU limit) during the year of 2023. (Davis, 2010) claims that raw water with turbidity less than 10 NTU can be treated only by filtration without sedimentation unit. Also, coagulation and flocculation rarely happen in raw water with turbidity less than 10 NTU. Under the light of that explanation, 339 days of the year turbidity of raw water under 10 NTU limitation and, and this is the reason for not obtaining good removal efficiency. To rephrase that, while 95% of time turbidity of the raw water <10 NTU, we cannot expect high efficiency of turbidity removal in the effluent of both treatment plants (Dokan-1 and Dokan-2).

Table 2: Characteristics of Turbidity Data Set.

Turbidity (NTU)	Mean (NTU)	Q1 (NTU)	Q3 (NTU)	95% percentile (NTU)
Raw Water	4.698	1.81	5.178	9.46
Dokan1-Effluent	3.265	1.565	3.566	6.098
Dokan2-Effluent	2.94	1.63	3.625	6.856

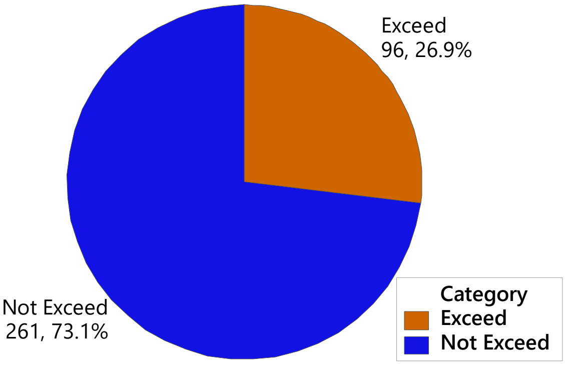

Figure 1. Turbidity evaluation of influent

(raw water) with 5 NTU limit.

Figure 2 describes the variation of influent and effluent turbidity for Dokan-1 and Dokan-2 WTPs. Several daily violations can be recognized for both treatment plants from Figure 3, the highest value of turbidity recorded for Dokan-1 WTP is 72.4 NTU on day 353 for the study year 2023. The highest recorded turbidity for Dokan-2 effluent is 19.7 on day 33. The other violations are not exceeding 20 NTU for both WTPs.

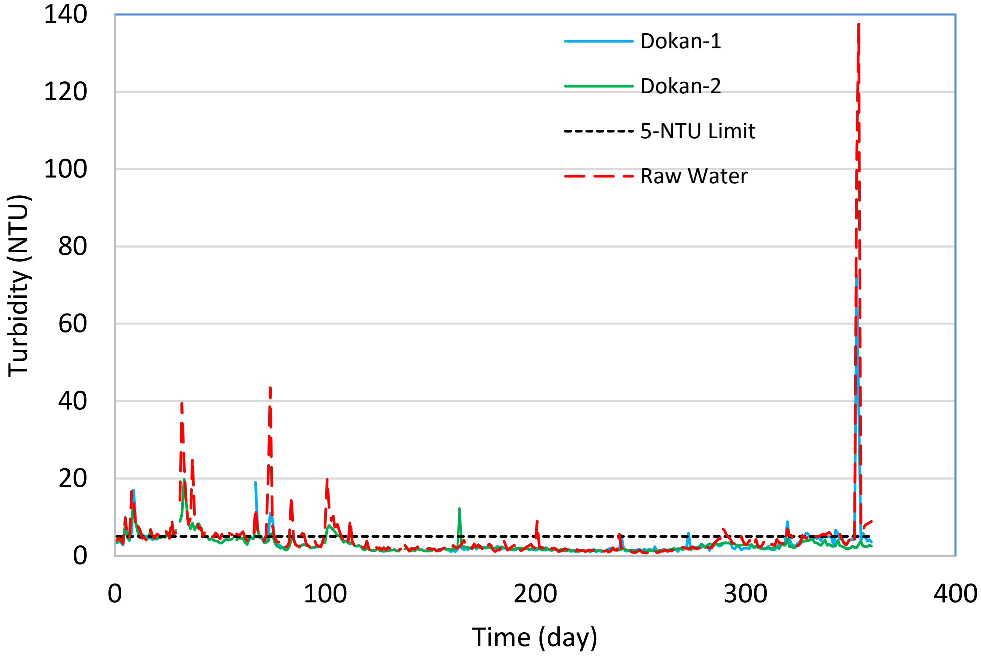

Figure 2. Turbidity variation for effluent from Dokan-1 and Dokan-2 WTPs

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According to (WHO, 2022) drinking water turbidity from zero up to 5 NTU would be acceptable and suitable for human consumption. Figures 3 and 4 show the percentage of daily violations of turbidity with the number of violating days beyond the 5 NTU limit for both plants, Dokan-1 and Dokan-2 respectively. During 2023, a percentage of 9.8% of daily data points from Dokan-1 effluent exceeded the 5 NTU limit of turbidity which is consists of 24 days in the year of 2023 (220 days out of 244 operating days the turbidity was below the 5 NTU limit, as shown in Figure 3). On the other hand, Dokan-2 WTP has 10.4% of daily records of effluent turbidity exceeding the 5 NTU allowable limit which means 37 days out of 357 days of operation during the 2023 year (320 days out of 357 days of operation the turbidity was below the 5 NTU limit, as shown in Figure 4).

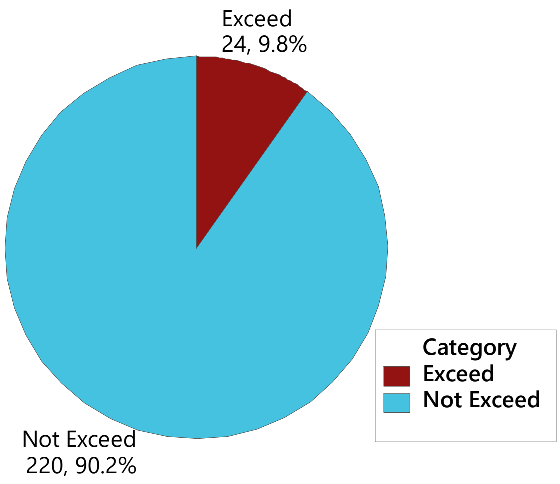

Figure 3. Turbidity Evaluation Dokan-1 WTP Effluent with 5 NTU limit.

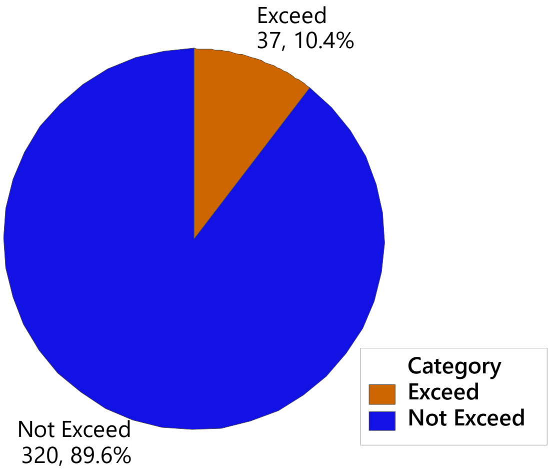

Figure 4. Turbidity Evaluation Dokan-2 WTP Effluent with 5 NTU limit.

3.2. Removal Efficiency Evaluation

Figure 5 shows the removal efficiency for both WTPs. From the figure it can be detected that for both plants, there are so many occasions of low efficiency and even negative efficiencies which may misunderstanding the observers with inefficient treatment processes. For example, the most extreme negative efficiency is for Dokan-2 WTP is -411.1% on day 164, and for Dokan-1 WTP the most extreme negative efficiency is -248.6% on day 273.

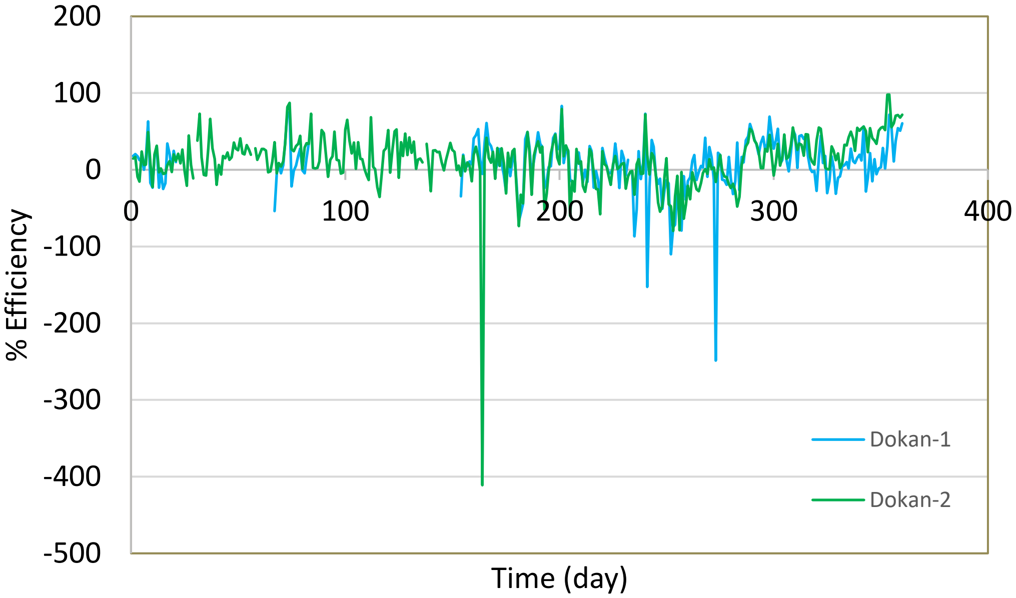

Figure 5. Turbidity removal efficiency for Dokan-1 and Dokan-2 WTPs.

Referring to the daily data (Figure 3) the influent turbidity for day 164 was 2.38 and the influent turbidity on day 273 was 1.705. Therefore, on the day of these two incidents, the influent (or the river water) turbidity was less than the 5 NTU limit, but the WTP raised the value of turbidity and impaired the quality of water at that day, and that incident is common on low influent turbidity days. Therefore, according to (Von Sperling et al., 2020), if influent turbidity (raw water) is less than 10 NTU it would be hard to reduce that turbidity with conventional treatment plants, Therefore, raising the turbidity due to release of clogged suspended particles in filter beds with that low turbidity water is expected to elevate the turbidity value which gives negative efficiency removal. In this regard, it would be better to cancel sedimentation units and by pass the water after flash mixers to filters. It would be more useful if membrane filters were used at those days with turbidities below 10 NTU, in this case the cost of treatment expected to be higher compared to the regular sand filters. Same scenario can be suggested for Dokan-1 WTP that has the lowest value of efficiency of -248.6 % on day 273, where the values of influent and effluent turbidities were 1.705 NTU and 5.97 NTU respectively on that day. This confirms our suggestion that if you feed a low turbidity water into a treatment plant, you would not expect a reasonable efficiency. Von Sperling et al.(2020) confirmed that obtaining a good efficiency (above 50%) in treatment of low turbidity raw water (<10 NTU) is not an easy task, therefore membrane filtration on those days would be more logical and cost effective, however a feasibility or cost-study should precede that decision.

3.4. Mean Removal Efficiency Assessment

Table 3 shows two different types of mean values of efficiencies for both WTPs. Staring at values of Table 3, it would be confusing which value of efficiency best represent the treatment plant efficiency, because the results of both efficiencies are quite different from each other. The more realistic value of efficiency is the mean efficiency of 23.8% for Dokan-1 and mean efficiency of 37.4% for Doakn-2 WTPs. As explained before for conventional treatment plants mean efficiency is the correct one, while using mean of efficiencies are misleading and not true to evaluate the WTPs. While, average efficiencies for both treatment plant are below 50%, but the effluent quality of water from both treatment plants are still good and acceptable, as shown in Figures 3 and 4. Percentage of acceptable effluent turbidity (below 5 NTU) of data points for both Dokan-1 and Dokan-2 WTPs are 90.2% and 89.6% respectively for the operating year of 2023 (Figures 3 and 4). Also 73.1% of daily records of influent (raw water) turbidity was below the maximum level of 5 NTU (Figure 1).

Table 3. Mean efficiency and mean of efficiencies for both WTPs.

Plant	Mean of Influent Turbidity (NTU)	Mean of Effluent Turbidity (NTU)	Mean Efficiency (%)	Mean of Efficiencies (%)
Dokan-1 WTP	4.29	3.26	23.82	5.24
Dokan-2 WTP	4.70	2.94	37.42	10.80

3.5. Evaluating of WTPs Performance Using Hypothesis Testing

To finalize the decision about the turbidity removal performance of the two WTPs, hypothesis testing executed to evaluate the effluent quality of water from both Dokan-1 and Dokan-2 WTPs. For that purpose, one sample t-test using the 95% confidence level performed for turbidity results from both treatment plants, hypothesis testing assumptions are as following:

H_0: μ ≤ 5 NTU

H_a: μ > 5 NTU

Where: H_0 is the null hypothesis, H_a is the research hypothesis and μ is the mean value of the turbidity. Table 4 shows t-test results for the both treatment plants, as the t-value < 1.645 and p-value > 0.05 of the tests for both WTPs confirms that the tests failed to reject the null hypothesis for being the turbidity equal to or less than 5 NTU. Therefore, the results of turbidity tests for both WTPs are equal or less than the 5 NTU, which means they are accepted according to specifications and the treated water from both WTPs are safe for human consumption in terms of the turbidity parameter.

Table 4. Effluent turbidity t-test results for both WTPs.

WTP	t- value	p-value
Dokan-1	- 4.97	1.00
Dokan-2	-18.49	1.00

3.6. Disinfection Evaluation

Existence of free chlorine (0.2 – 2 mg/L) in the WTP effluent is a sign of safe drinking water for human consumption. Figure 6 shows variation of residual free chlorine for both WTPs. Both plants have acceptable free chlorine dose around the allowable limit, except Dokan-2 WTP has only a single day violation with zero free chlorine on day 278. The values of average concentration of free chlorine were 1.35 mg/L and 1.63 mg/L for Dokan-1 and Dokan-2 WTPs respectively (Table 1).

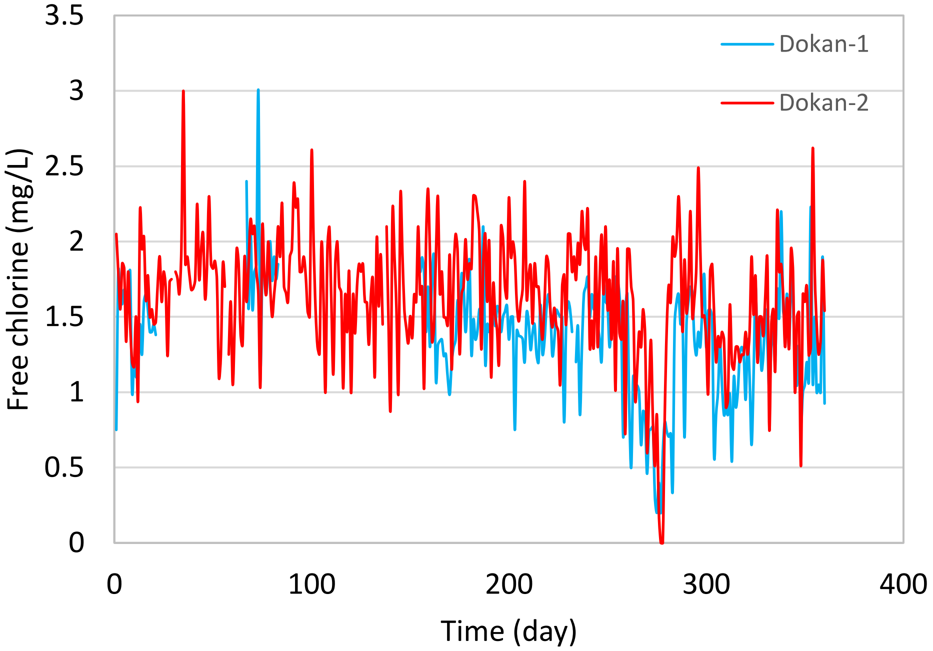

Figure 6. Daily Variation of free chlorine for Dokan-1 and Dokan-2 WTPs.

4. Conclusions

The two most fundamental parameters used to evaluate conventional WTPs performance are turbidity and disinfection. According to drinking water quality specifications, turbidity should not exceed 5 Nephelometric Turbidity Units (NTU), and the concentration of free chlorine should range from 0.2 mg/L to 2 mg/L. In this study, daily operational data from the year 2023 were used to evaluate the performance of two water treatment plants, Dokan-1 and Dokan-2, based on turbidity and chlorination parameters. To calculate average turbidity removal efficiency of conventional WTPs, the average daily turbidity at influent and effluent shall be used to calculate the average efficiency of the study period, hence, average of daily efficiencies should not be used. Although the first look at the results of this study shows that the average efficiency of turbidity removal is low (23.8% for Dokan-1 and 37.4% for Doakn-2). However, a closer look at the results illustrate that most of the time the effluent daily turbidity was acceptable (below 5 NTU), 90.2% for Dokan-1 and 89.6% for Dokan-2 WTPs. Whereas 73.1% of influent turbidity daily records were below 10 NTU, therefore high turbidity removal efficiency is not expected. Consequently, to make a fair decision about WTPs performance, efficiency is not the only criterion, but the values of influent of the turbidity also important. While obtaining a good efficiency (above 50%) in conventional WTPs with low turbidity raw water (<10 NTU) is not practical, therefore bypassing settling units to use direct filtration (especially membrane filtration) on those days would be more consistent and cost effective.

Results of the study also reveal that the quality of treated water, biologically, is acceptable and good for human use. For all daily records of 2023, free chlorine levels of the effluent from both WTPs were more than the 0.2 mg/L and less than 2 mg/L concentration of free chlorine, except for a single day violations for Dokan-2 which the free chlorine was zero. Hence, it is recommended to pay more attention to chlorine dose in Dokan-2 treatment plant to retain a higher concentration of residual chlorine.

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Declaration of Competing Interest

The author declare that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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