CWWQI on the Evaluation of Effluent Wastewater from Al-Dora Refinery WWTP

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Abstract. This study aimed to evaluate effluent wastewater from Al-Dora refinery wastewater treatment plant (DWWTP). The quality of wastewater for agricultural irrigation was evaluated using Canadian Wastewater Quality Index (CWWQI). Seven physical, chemical and biological parameters, namely, pH, SO₄, Cl, phenol, COD, BOD₅ and TDS were analyzed from April 2018 to March 2019. Results of CWWQI referred to variation in the acceptability of the treated wastewater for reuse in crop irrigation. The treated wastewater had CWWQI of 80.19, which reflects good quality. Hence, the treated wastewater was suitable for irrigation of many crops.

Keywords: wastewater quality index, evaluation, effluent, reuse.

1. Introduction

Al-Dora oil refinery is located in the southeast of Baghdad near the Tigris River and has a total area of 250 ha; this refinery was built in 1953 by the Iraqi government with the help of a group of foreign companies and started operation in 1955 [1, 2]. This refinery has a total capacity of 140,000 barrels per day and works on liquidation of crude oil and production of oil derivatives, such as white oil, gasoline, and diesel fuel [1]. The needs of treated water are divided into two types, namely, human and general needs and industrial consumption for liquidation. The refinery consumes large quantities of water, approximately 50,000 m³/day, for liquidation, and thus produces enormous amount of wastewater (WW), which can be processed by the treatment plant for refinery before reuse or dispose to the Tigris River [1, 3]. Al-Dora refinery wastewater treatment plant (DWWTP) was constructed in 1980 [2]. The average discharge of effluent wastewater is approximately 750 m³/h under normal operation and reaches 850 m³/h with overflow during rainy days.
Fig. (1) describes the schematic of DWWTP [2].

![DWWTP Schematic](image)

**Fig. (1).** DWWTP schematic [2].

This study used Canadian Wastewater Quality Index (CWWQI), which differs from Canadian Water Quality Index (CWQI) but maintains the same procedure. Developing countries, such as Iraq, have limited fresh water sources, which do not exceed 1%, and are the most arid zones on the earth [4, 5]. Water pollution occurs when contaminants spill into water sources without any treatment. Pollutants exert adverse effects on humans, animals, plants, and other biological complexes [6]. Reuse of WW could be a sensible choice to alleviate the shortage of new water assets in these districts; thus far, WW recycle and reuse has been widely recognized and employed in the agriculture water system field [4, 7].

Evaluation of the water quality of conventional sources depends on parameter-by-parameter appraisal of all influencing factors, either exclusively or through intelligent impacts [8]. Such investigation requires far-reaching information of drinking water science and may not provide precise and comprehensive results regarding the quality of drinking water sources [9]. The Canadian Council of Ministers of the Environment (CCME) introduced a WQI to rearrange the dissemination of water quality information [10]. The CCME WQI is a science-based specialized instrument that tests multiple variables of water quality against the benchmarks set by the client [9, 10]. WQI combines water quality factors to create a score indicative of weakness or reasonableness of utilization [8].

At present, the use of a file that describes and imparts information regarding the quality of WW source has not been completely investigated; moreover, the validity of any subsequent record scores has not been confirmed [8, 11]. The idea of wastewater source quality might have caused the absence of a list of viable wastewater quality. The calculation of WWQI should consider two factors that affect record advancement:

1. **Site particularity:** Parameters that should be considered in a specific area may not be of concern in other places and thus should be checked occasionally. A predictable arrangement of parameters is
not observed on a standard premise at all destinations; as such, elective files are required for consolidating all influencing parameters at all areas.

2. Treatment contemplations: Source WW is proposed for industrial and domestic utilization and thus should be treated. A file of source wastewater quality should consider the effect of treatment, both positive (chemical and biological inactivation) and negative (sterilization side-effects) and should be versatile to different treatment routines to precisely reflect quality.

CCME WQI provides an adaptable list format that is versatile to site particularity and treatment contemplations of source water. Specialists can choose suitable parameters and rules that can satisfy site explicitness and treatment contemplations for surveying the source of drinking water [12-14]. Amplitude is calculated using three separate procedures. Once the three variables are evaluated, CCME WQI is calculated using Eq. (1) [10]:

$$\text{CWWQI} = 100 - \left( \frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732} \right)$$

(1)

Where the variables \((F_1, F_2, \text{ and } F_3)\) are defined in the Eqs. 2, 3, and 4. The divisor 1.732 standardizes the resultant qualities to the range of 0 – 100, where 0 refers to poor water quality, and 100 refers to excellent water quality. WW quality is then ranked by relating it to one of the following classes:

| Class   | Range of CWWQI | Description |
|---------|----------------|-------------|
| Excellent | 95 – 100       | Water quality is protected and has no threat or impairment. Conditions are classified as natural or pristine or close to such levels. |
| Good    | 80 – 94        | Water quality is protected and has only a minor degree of threat or impairment. Conditions rarely depart from natural or desirable levels. |
| Fair    | 64 – 79        | Water quality is usually protected but occasionally threatened or impaired. Conditions sometimes depart from natural or desirable levels. |
| Marginal| 45 – 64        | Water quality is frequently threatened or impaired. Conditions often depart from natural or desirable levels. |
| Poor    | 0 – 44         | Water quality is almost always threatened or impaired. Conditions usually depart from natural or desirable levels. |

CWWQI was used to evaluate the quality of DWWTP. The general equation (Eq. 1) includes three variables \((F_1, F_2, \text{ and } F_3)\). \(F_1\) (scope) represents the percentage of the variables that quit from their objectives (Eq. 2), and \(F_2\) (frequency) indicates the percentage of the tests that do not match the objectives (Eq. 3) [10, 11].

$$F_1 = \left( \frac{\text{Number of failed variables}}{\text{Total number of variables}} \right) \times 100$$

(2)

$$F_2 = \left( \frac{\text{Number of failed tests}}{\text{Total number of tests}} \right) \times 100$$

(3)

\(F_3\) (amplitude) is counted based on an asymptotic topping capacity, which scales the standardized entirety of the excursions from the objectives \((nse)\) within 0 – 100 (Eq. 4) [10, 11]. \(F_3\) is determined in a three-step
process. First, excursion is evaluated. The number of times an individual parameter is more distant than (when the objective is a minimum, less than) the objective is selected as “excursion” and calculated by Eqs. 5 and 6. If the test value does not fall below the objective, then Eq. (6) is used.

\[ F_3 = \frac{n_{se}}{0.01n_{se} + 0.01} \quad (4) \]

\[ excursion_i = \left( \frac{\text{Failed Test Value}_i}{\text{Objective}_i} \right) - 1 \quad (5) \]

\[ excursion_i = \left( \frac{\text{Objective}_i}{\text{Failed Test Value}_i} \right) - 1 \quad (6) \]

Second, the sum of the excursions from the objectives is counted using Eq. 7. Finally, the CWWQI is obtained using Eq. 1. The scaling factor of 1.732 is used to rearrange the index between 0 and 100 [19].

\[ n_{se} = \frac{\sum_{i=1}^{n} excursion_i}{\text{Number of test}} \quad (7) \]

2. Materials and Methods

2.1 Sampling and measured parameters

Seven parameters were selected to calculate the CWWQI of the DWWTP and evaluate whether it is suitable for reuse in agricultural irrigation. Table 2 shows the categories of the parameters including five chemical parameters, one biochemical parameter, and one biological parameter. The standard specifications of Iraqi and the World Health Organization (WHO) [15] were used to evaluate the effluent characteristics of WW through CWWQI.

| Class | Type of Test | Standard Effluent Concentration (mg/l) |
|-------|--------------|----------------------------------------|
| pH    | Chemical     | 6.5 – 7.5a                             |
| SO_4  | Chemical     | 500 – 550                              |
| Cl^-  | Chemical     | 500 – 550                              |
| Phenol| Chemical     | 0.5b                                   |
| COD   | Biochemical  | 100 – 120                              |
| BOD_5 | Biological   | 40                                     |
| TDS   | Physical     | 450                                    |

a, unit less  
b, average value

The study was conducted for 12 months, from April 2018 to March 2019. Three tests were conducted for each parameter per month, and the total number of tests was 252. Standard tests were investigated in the Sanitary and Environmental Engineering Laboratory, Civil Engineering Department, University of Technology, Baghdad. Table 3 shows the standard methods for testing of the samples [16, 17].
Table 3. Standard methods used in laboratory to evaluate WW samples in four DWWTP samples.

| Test   | Type of Test | Standard Test      |
|--------|--------------|--------------------|
| pH     | Chemical     | APHA 4500-PB       |
| COD    | Biochemical  | APHA 5220B         |
| BOD₅   | Biological   | APHA 5210B         |
| SO₄    | Chemical     | APHA 4500-SO₄E     |
| Cl⁻    | Chemical     | APHA 4500-CLD      |
| Phenol | Chemical     | APHA 5530          |
| TDS    | Physical     | APHA 2540          |

In addition to WW pollutants, gases were detected using GIG IPA devices. The emitted gases include NOₓ, CO, SO₂, and H₂S and indicate the evaporation of organic gases, gaseous nitrogen, and sulfur gases from treated WW [18].

3. Results

3.1 Results of Examination

Table 4 shows the variations in the quality of the treated WW.

Table 4. Effluent concentrations of the tested parameters

| Period of Sampling | pH  | TDS  | COD  | BOD₅ | Cl⁻  | SO₄  | phenol |
|--------------------|-----|------|------|------|------|------|--------|
| Apr-18             | 7.8 | 830  | 44   | 10.0 | 216  | 390  | 0.043  |
|                    | 7.7 | 826  | 48   | 9.0  | 296  | 385  | 0.030  |
|                    | 7.6 | 740  | 44   | 9.0  | 256  | 310  | 0.045  |
| May-18             | 7.5 | 896  | 36   | 9.0  | 346  | 370  | 0.022  |
|                    | 7.7 | 980  | 40   | 10.0 | 296  | 355  | 0.030  |
|                    | 7.7 | 882  | 40   | 8.0  | 336  | 385  | 0.037  |
| Jun-18             | 7.5 | 896  | 150  | 6.0  | 295  | 355  | 0.040  |
|                    | 7.7 | 893  | 40   | 9.0  | 295  | 355  | 0.022  |
|                    | 7.7 | 920  | 48   | 10.0 | 316  | 370  | 0.030  |
| Jul-18             | 7.2 | 712  | 40   | 13.0 | 296  | 360  | 0.045  |
|                    | 7.4 | 740  | 44   | 6.0  | 316  | 360  | 0.040  |
|                    | 7.1 | 464  | 32   | 10.0 | 256  | 370  | 0.031  |
| Aug-18             | 7.2 | 770  | 32   | 5.0  | 282  | 357  | 0.040  |
|                    | 7.3 | 775  | 34   | 5.1  | 285  | 361  | 0.030  |
|                    | 7.6 | 765  | 35   | 5.3  | 288  | 380  | 0.041  |
| Sep-18             | 7.2 | 880  | 35   | 6.1  | 242  | 380  | 0.043  |
|                    | 7.3 | 815  | 35   | 6.6  | 240  | 350  | 0.030  |
|                    | 7.6 | 765  | 38   | 6.1  | 245  | 345  | 0.035  |
| Oct-18             | 7.6 | 890  | 50   | 6.1  | 194  | 149  | 0.039  |
|                    | 7.8 | 950  | 48   | 6.3  | 200  | 150  | 0.040  |
|                    | 7.7 | 820  | 53   | 6.6  | 193  | 200  | 0.031  |
| Nov-18             | 7.8 | 840  | 50   | 5.8  | 338  | 380  | 0.034  |
|                    | 7.6 | 950  | 45   | 6.0  | 331  | 510  | 0.030  |
|                    | 7.7 | 828  | 48   | 6.0  | 336  | 385  | 0.030  |
| Dec-18             | 7.1 | 740  | 44   | 9.0  | 365  | 310  | 0.050  |
|                    | 7.0 | 760  | 38   | 8.5  | 350  | 315  | 0.040  |
|                    | 7.0 | 720  | 45   | 8.8  | 359  | 308  | 0.034  |
| Jan-19             | 7.0 | 960  | 33   | 7.0  | 256  | 331  | 0.031  |
|                    | 7.1 | 950  | 40   | 6.7  | 255  | 338  | 0.045  |
Figs. 2 and 3 represent the variations in BOD$_5$ and COD with time, and Figs. 4 – 7 shows the variations in TDS, Cl$^-$, SO$_4$, and phenol.
3.2 Calculation of CWWQI

In this case, Eqs. 1 and 2 are applied.

\[ F_1 = \left( \frac{2}{7} \right) \times 100 = 28.57 \quad F_2 = \left( \frac{38}{252} \right) \times 100 = 15.07 \]

Alterations in Eqs. 5 and 7 yield:

\[ excursion_1 = \left( \frac{830}{450} \right) - 1 = 0.844 ; excursion_2 = \left( \frac{826}{450} \right) - 1 = 0.836 ; excursion_3 = \left( \frac{520}{500} \right) - 1 = 0.04 \]

\[ nse = \frac{0.844 + 0.836 + \ldots + 0.04}{252} = 0.1311 \]

So,

\[ F_3 = \frac{0.131}{0.01(0.131) + 0.01} = 11.58 \]

Hence, the CWWQI is determined as follows:

\[ CWWQI = 100 - \left( \frac{\sqrt{28.57^2 + 15.07^2 + 11.58^2}}{1.732} \right) = 80.19 \]

4. Discussion

This study aimed to assess DWWTP by using the CWWQI for the last 12 months. However, numerous WW quality samples were collected for DWWTP. CWWQI is a science-based specialized instrument that tests multivariable parameters for assessing WW quality information versus WW quality destinations indicated by the clients [20]. This tool also simplifies the reporting of WW quality data in technical and non-technical reports [11]. Site-specific wastewater quality objectives for each parameter were determined. The variables were relegated to territorial groups generally dependent on WW introduction to obtain adequate wastewater
quality information and determine site-specific objectives. The quality of the treated wastewater was assessed using two steps: 1) measurement of selected parameters of WW quality and 2) comparison to guidelines or objectives. However, evaluating the quality for each parameter and objective is quite difficult [21]. Therefore, a method that utilizes the combination of parameters should be developed. Moreover, the final value is a quality index that could be used by decision makers. The observed pH values are 7.0 - 7.5, which are within the permissible range according to the Iraqi standard [3]. Figs. (2) and (3) reveal the effluent concentrations of soluble organic matter by determining BOD5 and COD. All of the results are less than those predicted [3], thereby reflecting the satisfactory function of the aeration units and the biological reactors within the design range [22, 23]. Fig. (4) represents the variations in TDS concentration with time, and the values are higher than expected. This finding indicates that the biological reactors cannot remove all TDS. Good treatment of organic matter was observed, and some dissolved inorganic compounds were not adequately treated, leading to high TDS [15, 24]. Fig. (5) shows the variations in the effluent concentrations of Cl− with time, and the values are within the range of standard disposal for Iraqi standards [3]. However, the reason for the removal of Cl− back to the aeration processes in the WWTP [22]. In addition, the values of effluent SO4 are lower than those predicted based on the Iraqi standard (Fig. 6) [3]. This finding could be due to the removal of suspended SO4 in the sedimentation basins and dissolved SO4 in the biological reactors, consistent with the report of Tchobanoglous and Wang [22, 25]. Finally, phenols, which are hydroxy derivatives of benzene and its condensed nuclei, may occur in domestic and industrial wastewater, natural water, and potable water supplies [17]. Fig. (7) shows the variations in phenol with time, and the value is less than the standard [15]. Biological removal of phenol involves bio-chemical interaction. For example, phenol-decaying microscopic organisms, oxidizing and lessening substances, and basic pH esteem are managed by fermentation. Some much-debased WW may require specific procedures for dispensing with impedance and for quantitative recuperation of phenolic mixtures [15, 24]. In summary, the calculated CWWQI is 80.19, which indicates good quality of the treated WW.

5. Conclusion

This work assessed the quality of WW from DWWTP for reuse in agricultural irrigation. Multiple parameters were examined, and CWWQI was determined. The quality of treated WW was suitable for irrigation of many crops, such as grasses and ornamental plants, but inappropriate for food crops due to the presence of soluble organic matter, SO4, and phenol. Microbial contaminants considerably impaired the quality of effluent WW. As such, pathogens in the treated WW pose a danger to human health and cause pollution. Advanced treatments, such as rapid filtration, MBR, and disinfection, are recommended to protect the environment, farm workers, and animals.

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