Nature Environment and Pollution Technology
An International Quarterly Scientific Journal
p-ISSN: 0972-6268
(Print copies up to 2016)
e-ISSN: 2395-3454
Vol. 19 | No. 3 | pp.1057-1065 | 2020
Original Research Paper
https://doi.org/10.46488/NEPT.2020.v19i03.016
Open Access Journal

Assessment of Drinking Water Quality and the Efficiency of the Al-Buradieiah Water Treatment Plant in Basra City

Ahmed Sadiq Al Chalabi†
Department of Environmental and Pollution Eng., Basra Engineering Technical College,
Southern Technical University, Basra, Iraq
†Corresponding author: Ahmed Sadiq Al Chalabi; ahmed.sadiq@stu.edu.iq

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 14-08-2019
Revised: 25-09-2019
Accepted: 07-11-2019

Key Words:
Al-Buradieiah water treatment plant
Drinking water quality
Water treatment

ABSTRACT

This study was conducted on the oldest water treatment plant in the city of Basra, which is the Al-Buradieiah Water Treatment Plant (BWTP) during the period from December 2017 to March 2018. The study aimed to evaluate the efficiency of the plant by calculating the efficiency of sedimentation, filtration and sterilization basins, as well as to examine the water quality by examining the physical and chemical characteristics of raw water and treated water in this plant and then compare it with the World Health Organization (WHO) and Iraqi standards. The results of this study showed that the efficiency of sedimentation basins is 54%, while the efficiency of filtration basins is 24% and sterilization efficiency ranging from 37 to 65%. As well as, laboratory results of treated water quality have also shown that the turbidity equal to (7.24 NTU), electrical conductivity (EC) equal to 5040 μS/cm, the total dissolved solids (TDS) equal to 3380 mg/L and the total suspended solids (TSS) equal to 190 mg/L of the water outside from the BWTP. All these water quality results are higher than the WHO and Iraqi standard limitations except the value of pH, which is 6.9 and within the permissible limits.

INTRODUCTION

Water is the single most important substance for the sustenance of life known in the world. It is the elixir of life and without it, life is not possible. It represents a fundamental requirement for all life activities and is essential to humans, animals and plants (Fetter 1988). Its supply is endless as it covers over 80% of the earth's surface; however, only a small fraction of the water in the world is available for the human use (Sundstrom & K1ei 1979). Water is a vital liquid for maintaining life on earth. About 97% of the water that exists in oceans is not suitable for drinking and only 3% is freshwater, whereas 2.97% is comprised of glaciers and ice caps. The remaining 0.3% is available as surface and groundwater for human use (Miller 1997). Safe drinking water is a basic need for good health. Freshwater is already a limited resource in many parts of the world. During the next century, it will become even more limited due to increasing population, urbanisation, and climate change (Jackson et al. 2001).

Basra is the third largest city of the Republic of Iraq and is the administrative and political centre of the province of Basra, located in the far south of Iraq on the West Bank of Shatt al-Arab. It was the first water crossing in Iraq, and Basra is the economic capital with a population of about 2.5 million people, according to estimates in 2014. The Shatt al-Arab river consists of the confluence of the Tigris and Euphrates rivers in the region of Kerma Ali, at the northern entrance to the city of Basra, 375 km south of Baghdad. It is about 190 km long and is located in the Arabian Gulf at the edge of Al Faw city, which is the most extreme point in southern Iraq; in some areas, the width of the Shatt al-Arab river reaches two kilometres.

According to recent estimates, the quantity of available water in the developing regions of South Asia, the Middle East and Africa is decreasing sharply, while the quality of water is deteriorating rapidly due to fast urbanization, deforestation and land degradation. Therefore, many cities in Asia are facing an increase in organic and nutrient materials in drinking water due to the discharge of untreated domestic and industrial wastewater into these resources (Annachhatre 2006). The quality of water is affected by an increase in anthropogenic activities and any pollution, either physical or chemical, causes changes to the quality of the receiving water body (Aremu et al. 2011). The water quality and quantity audit include an analysis of historical water quality and quantity data, an evaluation of treatment system effectiveness, an investigation of customer satisfaction, an evaluation of monitoring and reporting practices, and an assessment of the water supply's future sustainability.

Similarly, during a study conducted in Iraq to evaluate the drinking water quality of the large treatment plant in the

Ramadi city at the Al-Anbar Province, the results indicated that the sedimentation unit has about 36% removal efficiency, which must be 70%-90%, the filtration unit has about 23.4% removal efficiency and the disinfection stage has about 97%-100% disinfection efficiency (Ramel 2010). Another study, conducted in Al-Fallujah, found that Al-Fallujah water treatment plant had an efficiency of 57% in the deposition, and an efficiency of 50% in the nomination phase and efficiency of 40%-90% in the sterilisation stage (Abdul Rahman et al. 2009). Another study conducted to evaluate the efficiency of Gas Al-Shamal water treatment plant showed that the plant was efficient for turbidity and total suspended solids removal. The results indicated that the characteristics of the total dissolved solids (TDS), total hardness (TH), electrical conductivity (EC), chloride (Cl), and sulphate were within the characteristic limits of Iraqi drinking water standards for raw and treated water. The results also showed that the (pH) values were beyond the suitable values of flocculation materials. The fluoride values of raw and treated water were low within the standards (Saleh et al. 2015). Another study assessed physical-chemical drinking water quality in the Logone valley (Chad-Cameroon); the samples were analysed for their physical-chemical and microbiological quality to identify contamination problems and suggest appropriate solutions. Results of the assessment confirmed that in the studied area there were several parameters of health and aesthetic concerns (Sorlini et al. 2013). Another study evaluated the quality of drinking water in urban areas of Pakistan (a case study of Gulshan-e-Iqbal Karachi, Pakistan). The results of the study demonstrated that the physical and chemical quality of water was satisfactory. Some samples (three) were possibly contaminated by leaking water mains and cross-connections between water mains and sewers due to proximity (Syed et al. 2016).

Study Area

The study area is located between Latitude (30°30’9.15”N) and Longitude (47°51’19.95”E), as shown in Fig. 1. Al-Buradieiah city is located in the province of Basra in the city centre, overlooking Shatt al-Arab through a small corniche. The Shatt al-Arab river limits Al-Buradieiah city from the east and Khurha River from the north. The Basra Water Project is big in the region for the distribution of drinking water to the population of the city. The water source of this plant is the Shatt al-Arab river. This station is equipped with all of the Aljaza’ar, Albradheah, Abbaseya, Mishraq, and Amtiha

Fig. 1: Map of the study area (BWTP).

regions; it has a design of 1500 m^3/h and its total capacity is 5000 m^3/hour. This station contains three projects:

1. The first project was in 1957 and had a capacity of 1500 m^3/h.
2. The second project was in 1964 and had a capacity of 1500 m^3/h.
3. The third project, which is called Al-Buradieiah station, was in 2012 and had a capacity of 2000 m^3/h.

The old project is considered better than the modern project due to the highly efficient English Company, while the modern project was conducted by the Turkish Company; its efficiency is lower but its design is better than the old project.

Basic Operational Phases in the Station

The station consists of several stages, as in Fig. 2.

1. **Drag system:** Consists of different capacity pumps; three pumps operate with a capacity of 2000 m^3/h and two pumps of 500 m^3/h capacity with a dive capacity of 1000 m^3/h.
2. **Adding alum:** Alum is added according to the value of turbidity, where alum is not added unless the turbidity value of 25 or above. In addition, there is a special lab with determines ratios added, according to the supervisor's instructions of the project in terms of the pumping power and the value of turbidity. The process continues for 24 hours.
3. **Sedimentation basins:** The station consists of four sedimentation basins; two basins for each of the first and the second project, in which they are circular and large in size (see Fig. 2), with a diameter of one basin at 24m and a height of 9m.
4. **Filters:** Each project consists of 14 candidates as the third project filters operate as a pressure filter, while filters of the first and the second project acts as a streamline filter.
5. **Placed chlorine system:** Liquid chlorine is added to water by chlorine placed device. The process of adding chlorine continues for 24 hours.
6. **Payment system:** The project consists of many payment pumps. These pump water through the pipes; the first and second projects contain four pumps, while the third project contains three.
7. **Ground reservoir:** Water enters the ground reservoir with a discharge of 2000 m^3/h only in the modern project.

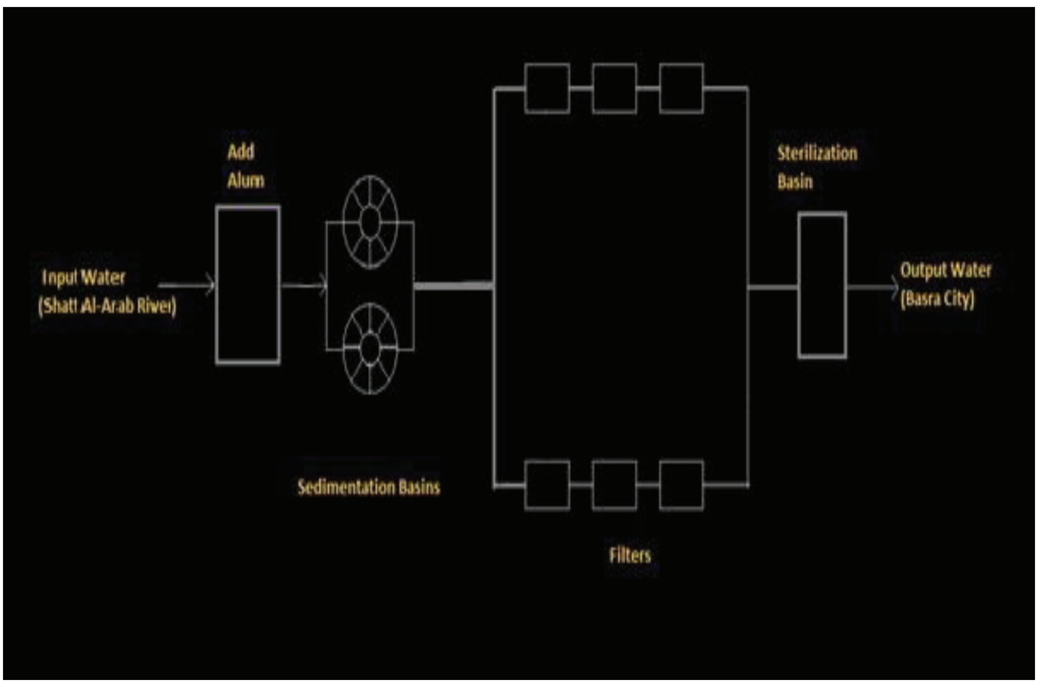

Fig. 2: The diagram showing the parts of BWTP.

MATERIAL AND METHODS

Sample Collection

Water samples were collected in plastic bottles with a capacity of 500 mL from each stage of purification at the station starting from the raw water (river water) to the outside of the station water (tap water). The samples of the sedimentation basin were taken at different depths (1.5, 3, 4.5, 6 and 7.5 metres away from the aquarium) and at a certain time (at 8:00 am). This was assumed to be the zero hour. Then the samples were taken on the same previous depths at different times, i.e. 1, 2 and 3 hours from the virtual zero hour, while the bio-screening water samples were collected in sterile plastic bottles over a period of four months (December, January, February, March) with three samples each month.

The standard methods (APHA 1998) were used for the analysis. The samples were analysed for different characteristic parameters such as pH, turbidity, electric conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS), magnesium, sulphates, and nitrates. Table 1 summarises the water quality parameters, the analytical methods, and the instruments used for the analyses (APHA 1998).

Efficiency of Sedimentation Basins

The ideal sedimentation basin design is based on the fact that when they put grain in a liquid, it is lower than its density, which is accelerated to that of regular speed and then equal to the weight of the submerged body with the power disability friction leading to deposition. When the stuck particles of different density are left to be deposited, there is different deposition speed of each particle from other particles; therefore, the speed of the particles is less dense and inflicted by the particles with faster speed (size or larger weight). This situation is generated by many collisions that lead to the union of the particle and composition of flocculants, especially when adding the adjuvant to form flocculants, such as alum. Alum is added to the solution at a rate of $4 g/m^3$ in the basin with rapid mixing. The calculation and estimation of the efficiency of a sedimentation basin require either the size distribution of the particles suspended or using sedimentation column, in which they draw equal removal curves (isoremoval curves). Samples are taken at different depths and different times for each depth, after knowing the concentration of suspended solids to raw water (C_0) and by taking samples (using a sedimentation column device) during a given time and then calculating the concentration of suspended material (C_1, C_2, ..., C_n) to different depths of the sedimentation basin (H_1, H_2, ..., H_n), which can be seen in Fig. 3. From the results of the sedimentation column experience the proportion of suspended particles can be calculated from equation (1) (Ahmed 1995):

$$S_{ij} = \frac{C_{ij}}{C_o} \tag{1}$$

Where,

S_{ij}: represent a percentage of solid particles remaining at a certain depth (h_{ij}) and a certain time (t_{ij}).

C_0: the concentration of total suspended solid particles of raw water units (mg/L).

Also, the percentage of particles removed (x_{ij}) for each depth and a certain weight can be found from equation (2):

$$E = 100 - X_0 + \left[\frac{1}{V_{So}}\right] \times \int_0^{X_0} V dx \tag{2}$$

Where,

X_{ij}: represents the percentage of particles that will be removed at a certain depth (h_{ij}) and a certain time (t_{ij}) and from which total removal can be calculated by the equation (3) (Ahmed 1995, Steel & Mcghee 1979):

$$E = 100 - X_0 + \left[\frac{1}{V_{So}}\right] \times \int_0^{X_0} V dx \quad ...(3)$$

Table 1: Water quality parameters and analytical methods for water source evaluation.

Parameter	Analytical method	Instrument
pH	Instrumental, analyse on site	EC500 - EXTECH (pH meter)
Turbidity	Instrumental, analyse on site	Turbi Direct - Lovibond
EC	Instrumental, analyse on site	Cond 3110 – WTW
TDS	Instrumental, analyse on site	EC500 - EXTECH (pH meter)
TSS	Gravimetric method	Gravimetric method SMEWW5520D
Magnesium	Photometric method	UV-2601-BIOTECH-Spectrophotometer, Ascorbic Acid Method
Sulphates	Photometric method	UV-2601- BIOTECH-Spectrophotometer, Ascorbic Acid Method
Nitrates	Photometric method	UV-2601-BIOTECH- Spectrophotometer, SMEWW 4500-NO_3

$$V_{S0} = \frac{Q}{A} \quad ...(4)$$

Where,

V_{S0}: represents the settling velocity (mm/sec)

The integration limit in equation (3) represents the shaded area of the chart in Fig. 4, which can be calculated using the Simpson theory or the Newton-Raphson theorem or by approximation of the graph (Ahmed 1995, Steel & Mcghee 1979).

Efficiency of Filters

The efficiency of the filters account for the disposal of suspended solids by finding the concentration of suspended solids in the water out of the sedimentation basin (Ce) in (mg/L), and then finding the efficiency of filters according to the equation (5) for the following:

$$E_f = 1 - \left(\frac{C_{out}}{C_e}\right) \times 100 \quad ...(5)$$

The Efficiency of the Sterilization Process (Disinfection) of Water

It is known that filtration does not work with great efficiency to remove bacteria and viruses, because of their small size, which is less than one micron, so quick sand filter does not produce potable water in the aspects of bacteriology. Chlorine must be added to remove bacteria and germs (Ahmed 1995). It is well known that the filtration does not work efficiently for the removal of bacteria. The degree of killed germs depends on the number of germs that are already present. The killing of germs depends on many factors that overlap with each other, such as the efficiency of the cleanser to penetrate the cell forces.

CALCULATION AND RESULTS

Sedimentation Efficiency

The samples from the sedimentation basin at different depths and at different times and extracting the concentration of the solids remaining suspended in each sample are given in Table 2. The calculated velocity and percentage of removal suspended materials are presented in Table 3.

Discharge of one basin = Total flow rate / No. of Basins

$Q = 2000/2 = 1000\ m^3/h$

$= 0.278\ m^3/sec$

Area of Basin = $\frac{\pi}{4} \times$ (Diameter of Basin)^2

$= \frac{\pi}{4} \times (24)^2 = 452.39\ m^2$

$V_{so} = \frac{Q}{A} = \frac{0.278}{452.39} = 0.000614$ m/sec

$= 0.614$ mm/sec

From Fig. 5, $X_0 = 58$ %

$E = (100 - 58) + (1/0.614) \times 7.21 \approx 54$ %

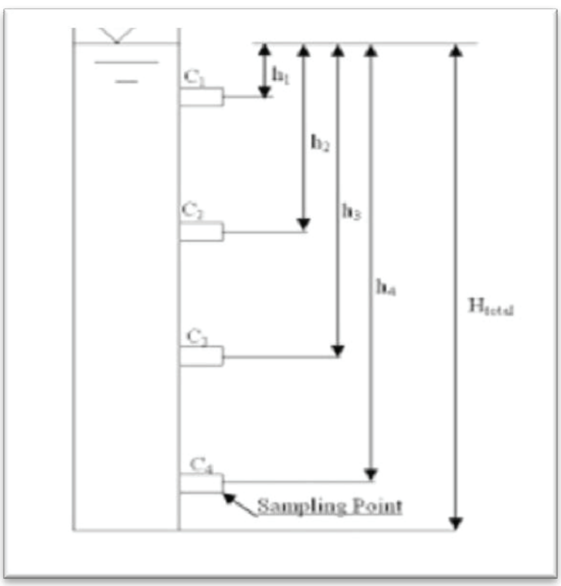

Fig. 3: Sedimentation column

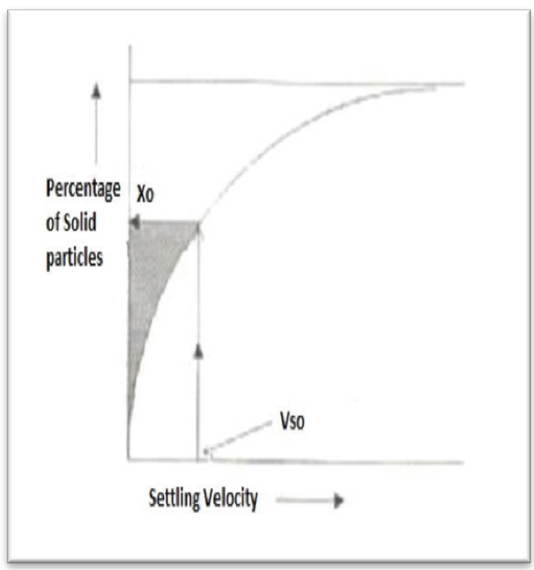

Fig. 4: Curved suspended material.

Table 2: Concentration of TSS for sediment basin samples.

Depth (m)	TSS (mg/L)			
	Settling Time (h)			
	0	1	2	3
1.5	325	100	160	170
3.0	325	60	220	140
4.5	325	30	200	110
6.0	325	20	170	100
7.5	325	10	130	50

Table 3: Results of velocity and percentage of removal suspended materials.

Depth (mm)	Time (sec)	Velocity (mm/sec)	Removal Solids	Removal per cent (%)
1500	3600	0.417	0.31	69
1500	7200	0.208	0.49	51
1500	10800	0.139	0.52	48
3000	3600	0.833	0.18	82
3000	7200	0.417	0.67	32
3000	10800	0.278	0.43	57
4500	3600	1.25	0.09	91
4500	7200	0.625	0.61	39
4500	10800	0.417	0.33	66
6000	3600	1.667	0.06	94
6000	7200	0.833	0.52	48
6000	10800	0.556	0.3	69
7500	3600	2.083	0.03	97
7500	7200	1.042	0.4	60
7500	10800	0.694	0.153	85

Efficiency of Filters

$$E_f = 1 - \left(\frac{C_{out}}{C_e}\right) * 100 = 1 - (190/250) \times 100 = 24\%$$

Efficiency of Sterilisation

Efficiency of Sterilization =

$$1 - \frac{\text{no.of bacteria outside of the station}}{\text{no.of bacteria inside the station}} \times 100$$

December → The efficiency of sterilisation =

$$1 - \left(\frac{44.5}{93}\right) \times 100\% = 52.15\%$$

January → The efficiency of sterilisation =

$$1 - \left(\frac{30}{86}\right) \times 100\% = 65.12\%$$

February → The efficiency of sterilisation =

$$1 - \left(\frac{43}{84}\right) \times 100\% = 48.8\%$$

March → The efficiency of sterilisation =

$$1 - \left(\frac{56}{90}\right) \times 100\% = 37.78\% \quad = 37.78\%$$

Water Quality

The properties of water, pH, turbidity, total dissolved solids, electrical conductivity, total suspended solids were examined. During the liquidation phases in the station, from the moment the water entered into the station and left for citizens, we determined from the test results that the pH of the water inside the station was 6.95 and outside 6.9 with the degree of pH affected by the addition of chlorine and alum to the water. Only the pH values were within the allowable limit in Iraq and WHO (Fig. 7); the water turbidity entering the station was 43.3 NTU but became 7.42 NTU after treatment. The turbidity of the water entering the filters was 15.6 (Fig. 8), which is high as it is supposed to be less than 10 NTU turbidity (Steel & Mcghee 1979). The total concentration of salt values was 8030 mg/L and 3380 mg/L of water inside and outside of the station respectively (Fig. 9), while the electrical conductivity was 5040 µS/ms for the water outside the station (Fig. 10). While the total suspended solids in the water were noted by the results of the tests, the raw water from the Shatt al-Arab river contained a high concentration of suspended solids valued at 325 mg/L (Fig. 11). The purification operations at the station experienced a reduction in this percentage, which significantly reached 190 mg/L of water coming out of the station but remained outside the boundaries of drinking water specifications (Table 4). Figs. 7-11 show these results.

The concentration of magnesium, nitrate and sulphate was also measured for the water entering the station and the water outside it and the calculation of the removal ratio is shown in Fig. 12. It was found that the concentration of magnesium inside the plant was 67mg/L, while the external concentration was 54mg/L, and the concentration of nitrate entering the station was 3.5mg/L and outside was 2.9mg/L. It was found that the concentration of sulphate inside the station was 433mg/L and the outside was 424mg/L. All these values are lower than the limits in Iraq and the WHO, except for the sulphate concentration (Table 4).

DISCUSSION

Through the results of calculations and tests that have been carried out in this research, the most important findings and their causes have been determined:

1. The efficiency of the sedimentation basin (54%) is not as good as the deposition process, which must rid the water of at least 90% of the particulate matter. The reason for this is that the station is lacking a device to identify the doses of alum, leading to not putting the appropriate amount of alum to get rid of the turbidity of the water. The alum used in the plant is considered to be outdated because of its old production.
2. The efficiency of the sedimentation tanks leads to the entry of water to the filters with high turbidity, as the specifications define turbidity as 10 units, preferably 5 units of water entering the filters (Steel & Mcghee 1979). However, it is noted that the value is higher than that (Fig. 8), which caused a decline in the efficiency of the filters

Table 4: Drinking water standards, according to the WHO and Iraqi Standard (WHO 2004).

Parameter	WHO in (mg/L)	Iraqi Standard in (mg/L)
pH (No units)	6.5-8.5	6.5-8.6
Total Hardness	100-250	500
Turbidity	5 NTU	5 NTU
TDS	500-1000	1500
EC	1000	1000
TSS	0	0
Iron	0.3-1	0.3
Manganese	0.05-0.1	0.1
Chloride	200-250	250
Magnesium	150	150
Sulphate	200-400	400
Fluoride	0.6-1.2	1
Calcium	150	200
Nitrate	50	50

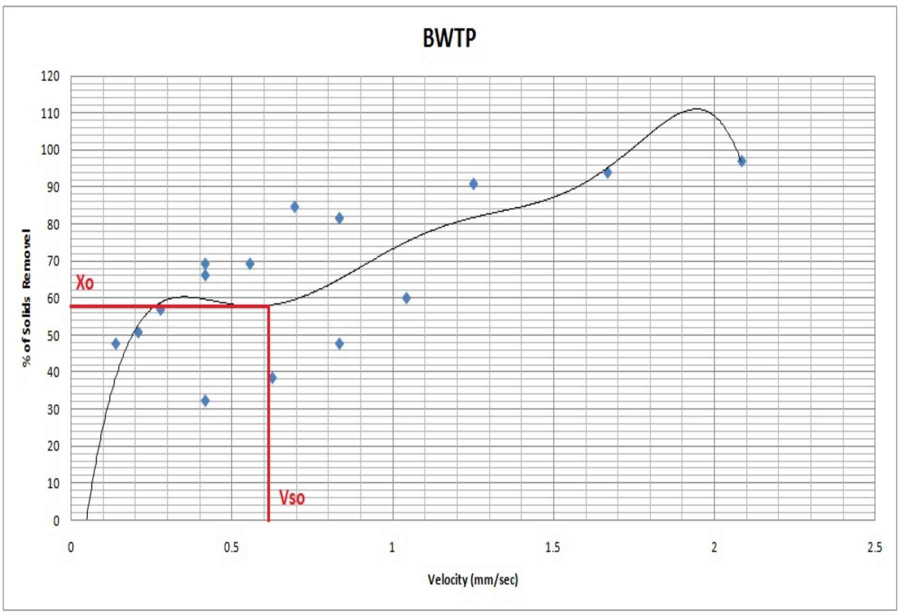

Fig. 5: Curved distribution of remaining suspended material.

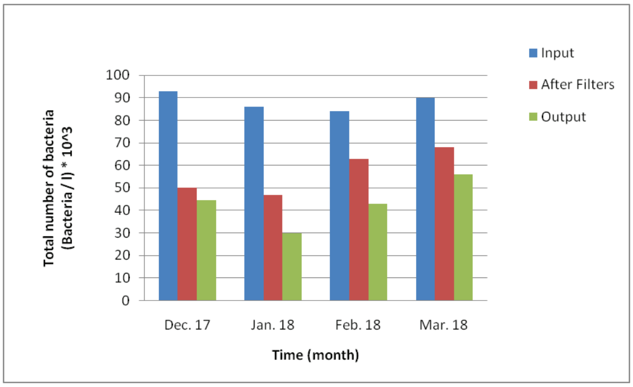

Fig. 6: Diagram showing the total number of bacteria.

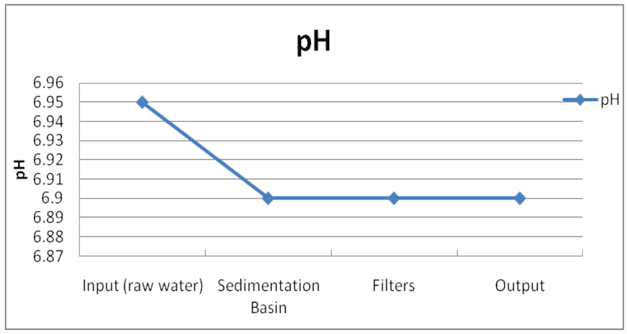

Fig. 7: Change in the value of pH in the stages of treatment in the BWTP.

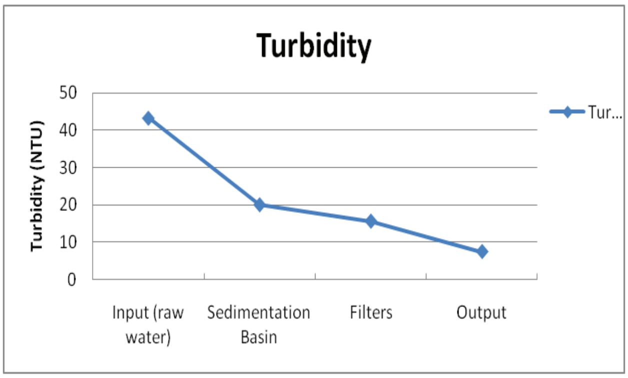

Fig. 8: Change in the value of turbidity in the stages of treatment in the BWTP.

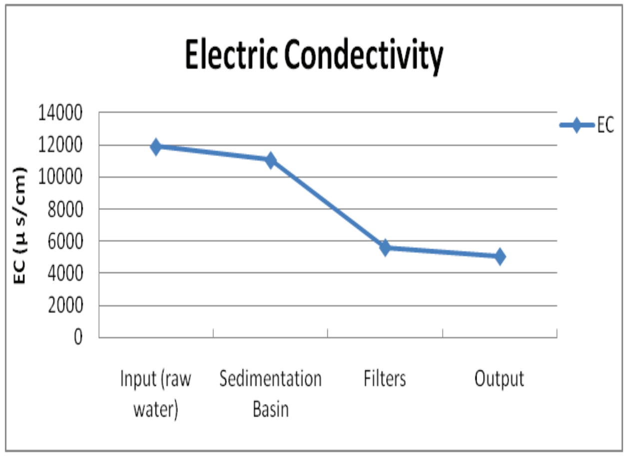

Fig. 9: Change in the value of EC in the stages of treatment in the BWTP.

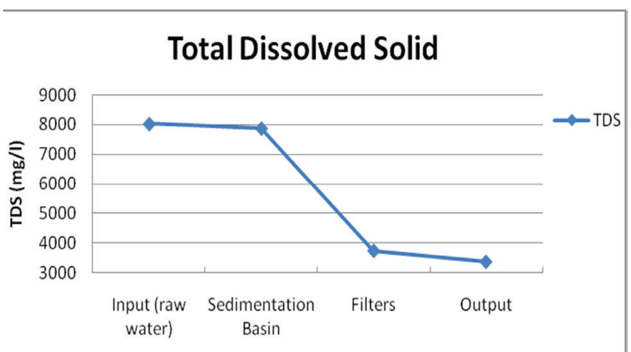

Fig. 10: Change the concentration of TDS in the stages of treatment in the BWTP.

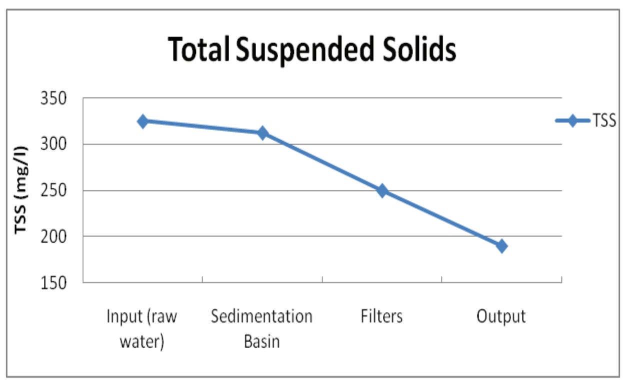

Fig. 11: Change the concentration of TSS in the stages of treatment in the BWTP.

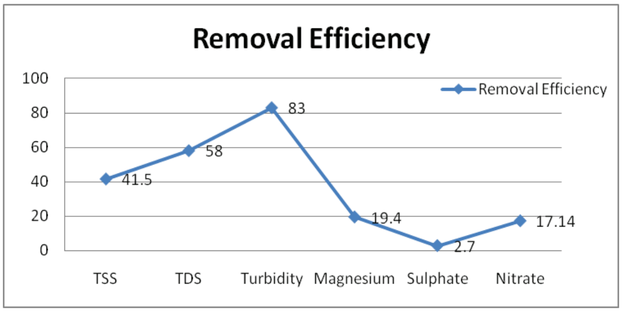

Fig. 12: The removal efficiency of water quality characteristics.

(24%) by a small percentage. Another reason for the low efficiency of the filters was the lack of substitution layers filters when they were needed. The replacement of filter layers was last completed five years ago and the lack of washing filters from time to time led to this result. The increase in the concentration of the suspended material to an allowable limit helps bacteria, viruses, and parasites to grow in the water causing pollution.

3. The results showed the total bacteria decreased in the water that the station was pumping to citizens (Fig. 6). According to US specifications, this water cannot be used for other purposes, e.g. the food industry because the bacteria can cause damage to processed food. Although the station added chlorine to improve the quality, it was unable to kill all the types of bacteria that were abounding in the cold weather. There is a range of factors that affect the reaction of chlorine to germs, with regard to cholera and other germs. Factors are related to chlorine (temperature, pH and the presence of organic matter) as chlorine reacts with the organic matter first and the rest reacts with germs.

CONCLUSIONS

1. Lack of efficiency of the station in terms of the efficiency of sedimentation, filtration and sterilization is desired for the removal of suspended solids in the water.
2. The station's different units do not perform well, especially when the plant is dealing with bad quality water.

RECOMMENDATIONS

1. Conduct similar studies on water treatment projects in the province.
2. The development of the water treatment process in the project by monitoring the quality of raw water per day and processed to suit the specifications of drinking water, by selecting the accurate dose of alum and coagulants in the laboratory, to control the amount of water in the processing units and periodic maintenance of processing units.
3. Perform general technical maintenance of the station stages and clean sedimentation basins.

REFERENCES

Abdul-Rahman, E.A., Mulood, A.A. and Whran, M.S. 2009. Assessment of the quality of drinking water and the efficiency of the water purification plant in Falluja. Iraqi Journal of Civil Engineering, 6(1): 27-38.

Ahmed, E.A. 1995. Environmental Engineering (5 ed.). Engineering College, Sultan Qaboos University, Al-Mustakbal Company, Oman, pp. 261-289.

Annachhatre, P. A. 2006. Water Quality and Wastewater Management. School of Environment Resources and Development & Asian Institute of Technology, Thailand, pp. 125-129.

APHA 1998. Standard Methods for the Examination of Water and Wastewater (20 ed.). American Public Health Association, Washington, D. C., USA.

Aremu, M.O., Olaofe, O., Ikokoh, P.P. and Yakubu, M.M. 2011. Physicochemical characteristics of stream, well and borehole water sources in Eggon, Nasarawa state. Chemical Society of Nigeria, 36 (1): 131-136.

Fetter, C. W. 1988. Applied Hydrogeology (2 ed.). Macmillan, New York, U. S. A., pp. 367-369.

Jackson, R.B., Carpenter, S.R., Dahm, C.N., Mcknight, D.M., Naiman, R.J., Postel, S.L. and Running S.W. 2001. Water in a changing world. Ecological Society of America, 9(1): 1-16.

Miller, G. T. 1997. Environmental Science: Working with the Earth (6 ed.). Wadsworth Publishing Company, California, U.S.A., pp. 423-481.

Ramel, M. M. 2010. Evaluating the drinking water quality supplied by the large treatment plant in Ramadi city. Al-Qadisiyah Journal for Engineering Sciences, 3(2): 33-56.

Saleh, R.A., Edaan, I.G. and Abdul Wahed, A.K. 2015. Evaluation of the efficiency of gas Al-Shamal water treatment plant. Diyala Journal of Engineering Sciences, 8(1): 1-12.

Sorlini, S., Palazzini, D., Sieliechi, J.M. and Ngassoum, M.B. 2013. Assessment of physical-chemical drinking water quality in the Logone valley (Chad-Cameroon). Sustainability, 5(1): 3060-3076.

Steel, E.W. and Mcghee, T.J. 1979. Water Supply and Sewerage. McGraw Hill Education Europe, New York, U.S.A., pp. 234-267.

Sundstrom, D.W. and Klei, H.E. 1979. Waste Water Treatment. Prentice Hall, Englewood Cliffs, U S A, pp. 3-6.

Syed, A.H., Alamdar, H., Urooj, F., Wajid, A., Amjad, H. and Nasir, H. 2016. Evaluation of drinking water quality in urban areas of Pakistan: A case study of Gulshane-Iqbal Karachi, Pakistan. Journal of Biodiversity and Environmental Science, 8(3): 64-76.

WHO 2004. Guidelines for Drinking Water Quality (3 ed., Vol. 1). World Health Organization, Geneva.