



[Science Archives \(ISSN:2582-6697\)](http://www.sciencearchives.org)

Journal homepage: [www.sciencearchives.org](http://www.sciencearchives.org)



<http://dx.doi.org/10.47587/SA.2021.2409>

Original Research Article



## Assessment of drinking water quality using the NSFQI model between source and consumer in Mosul city, Iraq

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Received: Nov 15, 2021 / Revised: Dec 16, 2021/ Accepted: Dec 24, 2021

### Abstract

In the current study, the water quality was evaluated using the NSFQI model for the Alaysar alqadim water supply plant and the residential quarters covered by the water supply, where water samples were collected from ten sites monthly (for one year) starting with the raw water entering the plant, after treatment and eight residential quarters sites are covered by the water distribution network, such as the quarters of Andalusia, Police, Nargal, Mohandessin, Agricultural, Al-Faisaliah, Al-Nabi Younis, Al-Darkaziliya, Al-Maliya, etc. The results of the quality index (NSFWQI) values indicated the relative deterioration of raw water before treatment due to bacterial contamination, as well as the increase in the number of total bacteria and the frequency of appearance of faecal coliform bacteria in most of the studied sites to reach (700) cell. ml<sup>-1</sup> and (16) cell. 100 ml<sup>-1</sup>, respectively, Therefore, it was classified in the category of good quality drinking water because the values of the NSFQI ranged between (73.8 to 78.6), since the studied physiochemical characteristics did not exceed the international standard limits.

**Keywords** Drinking water quality, NSFQI, Alaysar alqadim water supply plant

### Introduction

Preserving water in qualitative and quantitative terms means a healthy life, wealth, and economy is a blessing from God's grace to humans and all living organisms on our planet for its extremely important role in the biological activities and interactions of all living organisms, as it constitutes a large proportion of the weight of the organism, but the tampering and indifference with water resources made it threatened by the deterioration of its quality in many countries of the world as a result of civil, agricultural and industrial wastewater discharge to water sources without any treatment or inefficient treatment, especially third world countries, in addition to the challenges of global warming and droughts in large areas of the world (Al-Hamdani, 2021; Al-Mashhadany, 2021). Water is one of the important national and national security components for every country in the world, especially

countries located in arid and semi-arid areas whose water sources originate from neighboring countries such as Iraq, Egypt, Sudan, etc., which adds threats to the climatic challenges and the scarcity of rain, and the problem of deficit may turn Water is an economic and political weapon that is likely to lead to the possibility of tensions and wars, with the continued need for water. The future dimensions of Iraq may be dire due to external challenges such as the construction of dams and irrigation projects in upstream countries, as well as the processes of pollution and waste in local water consumption (Al-Hamdany et al., 2020; Al-Saffawi et al., 2021a). Today we are facing a crisis suffocating water that cannot be ignored as a result of the scarcity of water sources of water, so take scientific and practical solutions and good management to address the crisis and alleviate the water scarcity (Al-Barzanji, and Al-Saffawi, 2020).

One of the most important risks facing humans is the deterioration in the quality of drinking water resulting from the inefficiency of the drinking water treatment processes or because of pollution resulting from the aging and worn out of water pipes or the presence of breakage in the connection areas between them and thus the penetration of wastewater into the water pipes. This problem is widespread in many third world countries, including Iraq, because of negligence and abuses on the liquefaction pipes by connecting water pumps directly to them, which increases the possibility of water contamination with types of pathogens, which negatively affects consumers as a result of infection with many serious diseases that may end in death, such as *Salmonella typhi*, *Vibrio cholera*, *Shigellosis sp.* and *Giardia lamblia*, etc., especially children under the age of five (Al-Saffawi and Al-Assaf, 2018; Al-Saffawi, 2019).

Reports indicate that the number of diarrhoea cases for children officially registered only in Iraq in 2005 reached about one million cases, and in Nineveh Governorate 136 thousand cases, and that the number of cholera cases in Yemen between 2016 and 2017 is more than one million and more than two thousand deaths (Al-Taee, 2021) . In general, 75% of human diseases and more than 500,000 deaths a year in third world countries are caused by contaminated drinking water sources (Akhtar et al., 2019; Gunnarsdottir et al, 2020; Al-Taee, 2021).

Therefore, the current study came to assess the water quality of the Alaysar alqadim water supply plant and the quality of drinking water in the residential neighbourhoods covered by the distribution.

**Material and Methods**

**General description of the study area**

The Alaysar alqadim water supply plant was established on the northeastern side of the Tigris river in Mosul city in Alarabi quarter near the Nineveh Oberoi Hotel in 1963 as a traditional drinking water treatment plant (Hamed and Al-Sangeri, 2018), as a result of urban development and the increase in the population, it has been expanded to increase its productivity of water to cover the increasing need by the population. This project pumps water to the quarters of Andalusia, Police, Nargal, Mohandessin, Agricultural, Al-Faisaliah, Al-Nabi Younis, Al-Darkaziliya, Al-Maliya, etc. Table 1. and Fig.1 shows the locations of collecting water samples from the study area.

**Methodology**

In the current study, 10 sites were selected for monthly water sampling, which included, site 1: the water of the Tigris River (raw water), site 2: water after treatment, and the rest of the sites in the quarters covered by water distribution pipes. The sample collection process took place from March 2020 until February 2021 (120 water samples) using clean polyethylene bottles. As for the samples for measuring dissolved oxygen,

air-tight glass bottles were used and fixed in the field with the addition of Winkler reagent (A and B), and samples were collected for bacterial examination in sterile vials containing drops of sodium thiosulfate solution to inhibit the effect of chlorine according to (APHA, 1998). The water samples were transported to the laboratory in cool containers, away from light. Qualitative analyzes of aqueous samples were performed using standard methods as indicated (APHA, 1998, 2017).

**Table 1. Characteristics and coordinates of water sample collection sites from the Alaysar alqadim water supply plant and its quarters**

Sites	Longitude	Latitude	Elevation (m)	Uses
1	43°11'77"	36°39' 28"	224	For drinking, cooking, cleaning, bathing, washing clothes and cooking utensils
2	43°11'84"	36°39' 32"	222	
3	43°13'48"	36°37' 84"	223	
4	43°13'49"	36°37' 80"	221	
5	43°13'53"	36°37' 95"	224	
6	43°13'56"	36°37' 99"	222	
7	43°12'26"	36°37' 15"	223	
8	43°14'23"	36°37' 17"	223	
9	43°14'96"	36°35' 64"	226	
10	43°14'99"	36°35' 58"	222	



**Fig.1 A space map of the sites for collecting water samples from the study area**

**Estimation of water quality index (WQI)**

Water quality was estimated using the National sanitation foundation water quality index (NSFWQI) as one of the most widely used qualitative indicators in the world for its accuracy in determining the quality of drinking water. This model is characterized by giving one quick result of water quality that is understandable to any person, determining the qualitative changes of water in time and space, the environmental characteristics of the aquatic ecosystem, etc. (Dhere et al, 2019). Implement this mathematical model using the properties: Temperature, pH, TDS, TH, Cl<sup>-</sup>, SO<sub>4</sub><sup>2-</sup>, PO<sub>4</sub><sup>3-</sup>, NO<sub>3</sub><sup>-</sup> and Fecal coliform bacteria., and apply the following equations (Ewaid et al, 2018; Dhere et al, 2019; Ahmed et al, 2020; Hamadany, et al, 2021).

$$NSF-WQI \sum_{i=1}^n Li \times RWi \dots\dots(1)$$

whereas  $\sum_{i=1}^n RWi = 1 \dots\dots(2)$

Where, Li: Sub-Index for i<sup>th</sup> parameters ranging between (0.0 to 100), which is obtained from specific curves of (NSF-WQI) model., RWi: the relative importance weight associated with i<sup>th</sup> parameter and n: number of water quality parameters (Fathi et al, 2018; Al-Hamdany et al, 2020) as shown in Table 2.

**Table 2. Important Relative Weights (RWi) and Standards levels for nine properties used in the NSF- WQI**

Parameter	T. °C	pH	DO	EC <sub>25</sub> *	TH	SO <sub>4</sub>	PO <sub>4</sub>	NO <sub>3</sub>	F.C
RWi	0.10	0.11	0.17	0.08	0.08	0.10	0.10	0.10	0.16
Stand, levels	25	6.5 to 8.5	5.0	1400	500	400	10	45	0.0

\*TDS is found from the equation: (TDS = EC<sub>25</sub> × 0.64) to be used to find Li from the model-specific curves (Al-Tae, 2021)

After finding the values of the quality index, the water quality and category are known by referring to the Table 3. (Fathi et al, 2018; Dewata, 2019).

**Table 3. Criteria values, categories and classes of water quality (NSF-WQI)**

Values	0.0 to 25	26 – 50	51 - 70	71- 90	91 – 100
Categories	Very Poor	Poor	Medium	Good	Excellent
Classes	I	II	III	IV	V

**Results and Discussions**

The purpose of raw water treatment processes in water treatment plants is to produce potable water that is free from pathogenic microorganisms, has a pleasant taste, is colorless and odorless etc. (APHA, 1998). the results of the Water Quality Index (NSFWQI) indicate that it is a good tool for assessing the quality of drinking water because it takes the interactions between all the studied characteristics and gives a single value to indicate the quality of drinking water instead of the classic assessment of each parameter separately, which is a matter of confusion for the reader. As well as choosing the parameters that only affect water quality, taking into account not to use a large number of parameters to avoid confusion in the evaluation results (Al-Saffawi et

al., 2020). Where the results appear in Table 4. indicating that the average values of the water quality index (NSF-WQI) for site 1 (raw water from the Tigris River) amounted to (66), this relative deterioration of raw water quality is due to the effect of temperature, total dissolved solids, total hardness, sulfate and fecal coliform bacteria, where the values of (Li × RWi), reached (2.8, 4.80, 4.80, 6.40 and 3.30), respectively.

This relative increase in the concentration of pollutants and the numbers of fecal coliform bacteria contaminating raw water (Tigris River water) as shown in Table 5. is a result of the increase in the number of civil effluents drained into the Tigris River daily through many estuaries spread on both sides of the river, carrying with it many pollutants and huge numbers of bacteria. Al-Maadidi (2017) showed that the average number of fecal coliform bacteria was (54.3 x 10<sup>6</sup>) cells/100 ml at the confluence of Wadi Aqab with the Tigris River, north of Mosul city. This is confirmed by the results of the raw water, where the values of temperatures, solid dissolved materials, total hardness, sulfate ions and fecal coliform bacteria reached (20) °C, (502) uS. cm<sup>-1</sup> (340, 121) ppm and (1100) cell/ 100 ml<sup>-1</sup> consecutively.

**Table 4. (Li × RWi), values, category and class of water quality index (NSFWQI)**

Parameters	1	2	3	4	5	6	7	8	9	10
T.°C	2.80	2.50	2.20	2.20	2.50	2.50	2.10	2.10	2.20	2.20
pH	10.8	11.2	10.0	10.0	10.0	11.2	10.3	10.2	10.2	10.2
DO	15.2	16.5	16.7	16.7	16.5	16.0	15.9	16.3	16.3	16.3
TDS	4.80	4.96	5.04	5.04	5.12	5.20	5.20	5.20	5.20	4.64
T.H	4.80	4.88	4.80	5.28	5.28	5.04	5.12	5.28	4.64	4.56
SO <sub>4</sub>	6.40	5.50	7.20	6.40	5.70	5.80	5.80	6.30	6.20	6.10
PO <sub>4</sub>	9.50	9.50	8.20	7.30	7.50	8.20	4.10	5.40	4.50	4.80
NO <sub>3</sub>	9.40	9.60	9.40	9.40	9.50	9.60	9.5	9.50	9.50	9.50
F.C	3.30	16.3	14.9	15.2	14.7	14.4	14.4	15.0	14.7	14.9
WQI	66.9	80.9	78.4	77.5	76.8	77.9	72.4	75.3	73.4	73.2
category	M*	G**	G	G	G	G	G	G	G	G
Class	III	IV	IV	IV	IV	IV	IV	IV	IV	IV

\*M: Medium., \*\*G: Good

**Table 5. Water supply station analysis results for the old Esser project for water supply and residential Quarters covered by water distribution (ppm)**

Parameters	T <sup>o</sup> C	pH	EC	DO	T.H	SO <sub>4</sub>	PO <sub>4</sub>	NO <sub>3</sub>	F.C	TPC*	Cl <sub>2</sub>	
1	Min	11	8.14	378	6.40	216	49.5	0.09	0.16	2.3	1.78	0.0
	Max	20	8.21	502	11.2	340	121	3.43	1.14	1100	40.5	0.0
	Mea	16	7.81	419	8.70	282	87.9	0.60	0.46	82.4	10.5	0.0
	± Sd	3.3	0.19	40.5	1.48	40.2	20.0	0.95	0.27	42.3	0.17	0.0
2	Min	10	7.55	376	7.20	204	53.1	0.06	0.08	0.00	0.02	1.5
	Max	20	7.92	540	10.4	500	124	3.65	1.23	0.92	5.88	4.0
	Mea	17	7.73	429	9.0	301	91.2	0.59	0.39	0.12	1.32	2.5
	± Sd	4.0	0.12	49.3	1.14	77.8	22.8	0.98	0.38	0.29	0.02	1.0
3	Min	10	7.48	351	6.40	220	60.1	0.13	0.06	0.00	0.01	0.7
	Max	32	7.83	456	11.2	400	137	3.12	1.03	>16	6.04	2.0
	Mea	19	7.68	412	9.20	302	93.5	0.47	0.44	1.64	1.03	1.5
	± Sd	6.1	0.12	31.1	1.34	72.8	24.1	0.84	0.34	4.60	0.02	0.4
4	Min	8.0	7.37	376	7.20	196	43.6	0.1	0.15	0.00	0.00	0.3
	Max	33	7.97	477	11.2	380	129	3.16	1.45	0.51	3.32	2.0
	Mea	19	7.67	417	9.07	277	79.9	0.60	0.51	0.12	0.67	1.3
	± Sd	6.7	0.16	32.4	1.29	60.0	29.8	0.90	0.41	0.02	0.10	0.7
5	Min	8.0	7.54	376	8.00	200	38.9	0.12	0.06	0.00	0.01	0.3
	Max	24	7.79	473	11.2	300	150	2.95	7.08	1.60	6.60	2.0
	Mea	17	7.68	419	9.46	252	85.7	0.51	1.29	0.19	1.53	1.4
	± Sd	4.3	0.1	31.7	1.01	40.5	30.9	0.79	2.34	0.47	0.02	0.5
6	Min	9.0	7.57	373	8.00	180	41.2	0.05	0.03	0.00	0.03	0.1
	Max	22	7.80	466	11.2	400	166	1.40	3.16	0.92	3.96	2.2
	Mea	17	7.70	416	9.13	280	84.9	0.46	0.57	0.14	1.10	1.4
	± Sd	3.8	0.1	30.4	1.15	79.0	35.1	0.42	0.83	0.29	0.01	0.6
7	Min	10	7.56	373	7.20	188	48.3	0.11	0.09	0.00	1.05	0.1
	Max	28	7.91	458	10.4	420	145	3.06	2.51	>16	7.00	1.5
	Mea	19	7.77	400	8.80	278	82.6	0.91	0.57	0.20	2.05	0.8
	± Sd	5.3	0.1	32.6	0.96	72.0	29.9	1.18	0.66	0.63	0.03	0.5
8	Min	9.0	7.57	364	6.40	180	44.8	0.09	0.17	0.00	0.02	0.1
	Max	28	7.91	496	10.4	420	145	3.71	8.13	>16	6.92	1.5
	Mea	20	7.76	406	8.40	281	78.6	0.77	1.39	0.46	1.23	0.7
	± Sd	6.3	0.11	38.9	1.58	75.5	28.6	1.12	2.42	1.47	0.06	0.4
9	Min	11	7.50	360	7.20	180	47.1	0.08	0.14	0.00	0.02	0.3
	Max	27	7.82	474	11.2	400	152	3.48	2.86	>16	6.00	3.0
	Mea	19	7.69	413	9.40	266	83.5	0.79	0.69	1.91	1.53	1.2
	± Sd	5.2	0.1	34.7	1.28	68.8	32.7	1.14	0.72	4.71	0.02	0.7
10	Min	9.0	7.5	373	6.40	180	47.1	0.08	0.03	0.0	0.00	0.3
	Max	28	8.04	465	11.2	460	169	3.39	3.10	16.0	6.40	3.0
	Mea	19.4	7.71	412	8.93	260	87.3	0.81	0.59	1.75	1.15	1.3
	± Sd	5.82	0.14	30.0	1.40	80.3	41.47	1.04	0.82	4.71	0.02	0.7

\* × 100 Cell. ml<sup>-1</sup>, \*\* Cell. 100 ml<sup>-1</sup>



As for the water after treatment in Al-Yaser station (location 2), it was of good quality for drinking water, with a quality index value of (80.9), which indicates the good efficiency of the drinking water processing plant for consumers. Likewise, with the rest of the sites, the values fluctuated between (72.4 to 78.4) and this relative fluctuation in quality is due to the effect of temperature, TDS, TH, SO<sub>4</sub>, with a clear effect of phosphate ions, nominally at sites (7, 8, 9, and 10), where the values of (Li × RWi) decrease relatively to range from (4.1 to 5.4) with the clear decrease in the number of bacteria, which caused the values of (Li × RWi) a rise to range between (14.4 to 16.3) in all sites except for raw water, this is due to the treatment efficiency in Alaysar alqadim water supply plant, with a relatively acceptable concentration of chlorine, which ranged between (1.31 to 2.5) ppm as shown in Table 5. It is also noted that the concentration of phosphate ions increases relatively in sites (7, 8, 9, 10) to range between (3.06 to 3.77) ppm, with the relative increase of fecal coliform bacteria clearly in these sites to reach (16) cells. 100 ml<sup>-1</sup>. This negatively affected the quality of drinking water, and this is likely due to the residents connecting water pumps directly to the pipes of the water supply network, allowing the contaminated water to enter the water pipes.

## Conclusions and recommendations

The treatment operations of Alaysar alqadim water supply plant were of good quality because all the sites under study were of good quality.

Most of the physical and chemical properties of the studied water samples did not exceed the international standard limits for drinking water, while the frequent appearance of bacteria and fecal coliforms in some water samples, which has negative effects on the health of consumers.

Despite the lack of fecal coliform bacteria in some water samples and their frequent appearance in some water samples, this negatively affects the health of consumers.

Therefore, the study recommended emphasizing the periodic bacterial examinations of drinking water, while activating the application of deterrent laws for violators by linking water pumps to the water distribution network to preserve the consumer's health.

## Conflict of Interest

The authors announce that there is no conflict of interest with respect to the publication of this article.

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**How to cite this article**

Manal A. A. Al-Hamadany, Abdulazez Y.T. Al-Saffawi, Yousef J. Al-Shaherey (2021). Assessment of drinking water quality using the NSFQI model between source and consumer in Mosul city Iraq. *Science Archives*, Vol. 2 (4) 324-329. <http://dx.doi.org/10.47587/SA.2021.2409>

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