DOI: https://doi.org/10.54809/jkss.vi1.61

گۆڤاری کوردستانیی بۆ لێکۆڵینەوەی ستراتیجیی

Assessment of water quality index (WQI) in the water distribution system in Kalar, Sulaymaniyah, Iraq

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Abstract

In this research, Water Quality Index (WQI) was mathematically assessed to determine water quality at (Bardasoor Treatment Plant – Kalar) and at different points within the neighbourhoods, away from some distance from the treatment plant to check the quality of water in the distribution network. A water sample was collected from the input point at Bardasoor Treatment Plant before the process of treatment, and another sample was collected after the treatment process and before the distribution process. As well, (40) samples of water were collected at (8) stations and were all subjected to Physico-chemical tests. The index classified the quality of water within the water distribution system in Kalar as (good quality) except (2) stations which were classified as (poor quality); despite, some parameters works compete unfavourably with (WHO) standards.

Keywords: Bardasoor treatment plant, Kalar City, Water Quality, Water Quality Index (WQI), water distribution system

Recieved: 31/1/2022
Accepted: 28/2/2022

E-ISSN: 2790525-X
P-ISSN: 27905268

1 Introduction

Surface water is a significant source of water available in rivers and reservoir, and are used for various purposes such as drinking, irrigation, and fish culture. Nowadays, and as a result of worldwide increasing population and pollution, surface water has become a significant issue [1]. Usually, water quality decreases as a result of increased anthropogenic activities. Moreover, agricultural practices such as using pesticides and fertilizers have great impacts on the quality of surface water resources [2]. Water quality management for drinking purposes must be focused on diseases prevention; so that, it may transmit diseases and pollutants in many cases [3].

Therefore, drinking water has to be fit with human needs. Also, water supplies must be suitable for all domestic uses. Domestic water supplies are usually subjected to pollutants that are directly introduced into the water distribution system from the treatment plant, erosion and through pipe leakages [4]. Water Quality Index (WQI) which has been used in this study is an indicator of water pollution. Also, it is a tool utilized to determine the quality of water by using some physicochemical parameters. So, WQI expresses ultimate water quality at a certain station by providing single values. This study aimed to investigate the classes of WQI before and after the process of water treatment at Bardasoor Water Treatment Plant WTP, and also at different points in the residential neighbourhoods in Kalar City.

2 Study Area

This study has been conducted in Kalar City (Figure 1), which is a part of the Kurdistan Region in Iraq. The city is located between latitudes (34, 38 – 34, 35) degrees north and longitudes (45, 15 – 45, 21) degrees east. The city is (300-355) m above sea level. Its area is about 32 km2 and is located on the southeastern side of Kirkuk governorate, 150 km away, and on the south of Sulaymaniyah Governorate, 140 km away, and north of Baghdad, 180 km away, and close to the western border of Iran, 35 km away [5].

2 Materials and Methods

2.1 Water Sampling: In this research, 2 samples of water were taken from the intake unit before the treatment plant (Bardasoor WTP) and after the treatment. Also, 40 samples were taken from taps in different stations within a water distribution system. Each sample of water was collected in a container of (1) litre, and one-inch space was left for air under the cover in each sample. The samples then were covered, labelled and sent immediately to the laboratory to be tested without delay.

2.2 Analysis of Water Samples: Some physicochemical parameters including pH, EC, TDS and turbidity were directly measured on-site. Other chemical parameters were measured by inductively coupled plasma optical emission spectroscopy (ICPOES) [6].

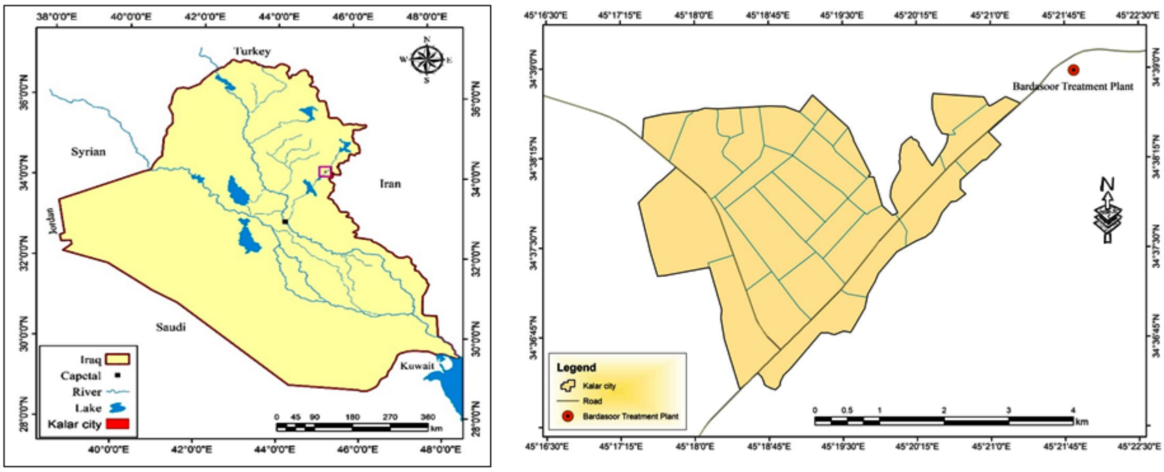

Figure (1): Kalar City and Bardasoor Water Treatment Plant

2.3 Water Quality Parameters and WQI: Nine water quality parameters were analyzed following the drinking water quality standard which was recommended by the (WHO) [7]. These parameters include: turbidity, pH, EC, TH, TDS, Ca+2, Mg+2, Fe+2 and F+. The main reason for choosing these parameters is that they are most relevant to human health. The method of weighted arithmetic index [8] was applied on the average values of each parameter in each suburb (Stations) to calculate WQI using the following equation:

(WQI) = Water Quality Index, (Wi) is the weight unit for the (nth) parameter. (qi) is the Quality rating for the (nth) quality parameter. Further, the Sub-index or quality rating (qi) was calculated by using the following equation:

(i) is the parameter of water quality, (Vi) represents the estimated value of the (nth) parameter at each station, (Si) is the permissible value for the (nth) parameter. (Vid) represents the ideal value of each parameter (nth). Zero was set for all the parameters except pH which is set as 7:

/ (8.5-7.5)]

The value of the water quality index (WQI) and the level of water quality status was determined based on the Weighted Arithmetic Index method as shown in Table (1) and (2):

Table (1): Levels of (WQI) and water quality status (WQS) based on the Weighted Arithmetic Index method [8] [9].

WQI	WQI Status
0–25	Excellent
26–50	Good
51–75	Poor
76–100	Very poor
Bove 100	Unsuitable for drinking

Table (2): Weights for the WQI Parameters

Parameters	BIS Standard(Sn)	Weight	IDEAL Value (Vo)
pH	8.5	0.02501	7
EC	600	0.00035	0
TDS	500	0.00043	0
TH	500	0.00043	0
Ca	75	0.00283	0
MG	30	0.00709	0
Fe	0.3	0.70872	0
Flouride	1	0.21262	0
Turbidity	5	0.04252	0

3 Results and Discussion

The obtained results are presented in table (3). In this study, water quality index (WQI) calculations have been carried out based on drinking purposes.

3:1 pH

It indicates the differentiation in water quality and is affected by dissolved elements in the water. [10]. For all the water samples, pH minimum and maximum values were observed to be (7.33) and (7.89) respectively. Therefore, these values indicate that all water samples are within the limits of (the WHO) standard for drinking purposes. The pH value of intake point at Bardasoor Treatment Plant before the process of treatment is (8.14); however, pH value after-treatment process and before distribution process is (7.88).

3:2 Electric conductivity and TDS

Electric conductivity EC is the measuring the amount of dissolved solids that hold negative or positive charges in water [11]. The values of EC for all water samples are varied between (574) to (603) µmho/cm. Based on (WHO 2011) standards, the permissible value of (EC) is (600 µmho/cm) [12].

TDS is related directly to electric conductivity, dissolve substances including (salts and minerals) in water may produce undesirable taste [13]. The (WHO 2009) standard value for total dissolved solid TDS is (500 ppm). The results show that TDS concentrations in Kalars' suburbs are range between (366.93- 385.47) ppm, and the values of TDS in intake point and output point within Bardasoor Treatment Plant are (342) and (335.61) respectively. Therefore, the values of TDS in all the stations in the present study were below the standard level.

Table (3): results of the studied parameters in the study area

Station	Location	Sample No.	Turbidity NTU	pH	EC µmho/cm	Ca mg/l	Mg mg/l	Fe mg/l	F mg/l	TDS mg/l	TH mg/l
0	Intake WTP		25.9	8.14	535	9.19	3.5	0.15	0.93	342	37.36
Control	Outlet of WTP		4.83	7.88	525	9.38	3.57	0.11	0.22	335.61	38.12
A	Azadi	1	7.45	7.72	589	11.992	4.473	0.11	0.72	376.52	48.36
		2	7.98	7.898	583	11.317	4.125	0.13	0.46	372.68	45.25
		3	7.24	7.652	599	11.541	4.255	0.12	0.44	382.91	46.34
		4	7.12	7.674	590	11.882	4.358	0.12	0.42	377.16	47.62
		5	6.12	7.623	587	11.563	4.245	0.13	0.35	375.24	46.35
		Average	7.182	7.71	589.6	11.66	4.29	0.122	0.48	376.90	46.78
B	Farmanbaran	6	4.11	7.335	587	12.027	4.41	0.16	0.4	375.24	48.19
		7	5.28	7.552	595	12.411	4.482	0.14	0.39	380.36	49.45
		8	5.82	7.775	593	12.158	4.395	0.14	0.39	379.08	48.46
		9	3.97	7.645	587	12.48	4.561	0.17	0.36	375.24	49.94
		10	3.17	7.598	586	11.883	4.293	0.14	0.35	374.60	47.35
		Average	4.47	7.58	589.6	12.19	4.43	0.15	0.38	376.90	48.68
C	Sherwana	11	6.4	7.606	593	12	4.125	0.18	0.29	379.08	46.95
		12	9.95	7.568	586	12	4.125	0.16	0.33	374.60	46.95
		13	3.81	7.573	578	12	4.125	0.15	0.3	369.49	46.95
		14	5.43	7.77	595	12	4.51	0.14	0.35	380.36	48.54
		15	3.84	7.804	582	12	4.39	0.15	0.32	372.04	48.04
		Average	5.89	7.66	586.8	12	4.26	0.16	0.32	375.11	47.49
D	Sirwan	16	3.71	7.525	580	12.66	4.51	0.15	0.31	370.77	50.18
		17	3.94	7.555	603	12.16	4.31	0.14	0.34	385.47	48.11
		18	3.94	7.548	580	12.54	4.45	0.16	0.33	370.77	49.64
		19	3.36	7.67	580	11.93	4.35	0.13	0.31	370.77	47.70
		20	3.66	7.536	581	12.34	4.41	0.13	0.32	371.41	48.97
		Average	3.72	7.57	584.8	12.33	4.41	0.14	0.32	373.83	48.92

E	Gazino	21	3.76	7.505	578	11.93	4.23	0.12	0.27	369.49	47.21
		22	4.55	7.588	582	12.15	4.4	0.13	0.25	372.04	48.46
		23	5.05	7.529	581	12.56	4.48	0.12	0.25	371.41	49.81
		24	6.14	7.59	578	12.95	4.67	0.11	0.31	369.49	51.57
		25	5.49	7.5	581	11.71	4.24	0.14	0.27	371.41	46.70
		Average	5.00	7.54	580	12.26	4.40	0.12	0.27	370.77	48.75
F	Sarkawten	26	4.67	7.726	588	12.28	4.33	0.15	0.25	375.88	48.49
		27	4.57	7.795	582	12.48	4.45	0.14	0.26	372.04	49.49
		28	4.06	7.733	581	12.29	4.37	0.15	0.35	371.41	48.68
		29	4.48	7.466	579	12.45	4.47	0.16	0.28	370.13	49.50
		30	4.69	7.676	574	12.54	4.5	0.14	0.22	366.93	49.84
		Average	4.49	7.68	580.8	12.41	4.42	0.15	0.27	371.28	49.20
G	Goran	31	4.9	7.549	591	12.29	4.42	0.16	0.25	377.80	48.89
		32	4.57	7.853	588	13.16	4.57	0.13	0.19	375.88	51.68
		33	5.86	7.493	575	12.11	4.39	0.14	0.22	367.57	48.32
		34	5.66	7.514	582	12.8	4.57	0.15	0.23	372.04	50.78
		35	5.02	7.477	582	13.21	4.76	0.15	0.22	372.04	52.59
		Average	5.20	7.58	583.6	12.71	4.54	0.15	0.22	373.07	50.45
H	Bardasoor	36	6.12	7.552	579	12.79	4.51	0.11	0.25	370.13	50.51
		37	7.66	7.804	596	12.77	4.47	0.11	0.25	380.99	50.29
		38	7.77	7.643	586	13.53	4.83	0.13	0.21	374.60	53.67
		39	6.56	7.585	590	14	5.02	0.12	0.21	377.16	55.63
		40	10.97	7.691	585	13.94	4.99	0.13	0.23	373.96	55.36
		Average	7.82	7.66	587.2	13.41	4.76	0.12	0.23	375.37	53.09
Min			3.17	7.335	574	11.32	4.13	0.11	0.19	366.9	45.25
Max			10.97	7.898	603	14	5.02	0.18	0.72	385.5	55.6
WHO St.			5	6.5 - 8.5	600	200	150	0.3	1-1.5	500	500

3:3 Turbidity

It is the presence of a high quantity of suspended material; so, water with a high level of turbidity may develop gastrointestinal diseases for people [14] . The values of turbidity in all the stations are between (3.17- 10.97 NTU). The turbidity values in most of the stations (13 stations) are higher than the set limits of (5 NTU). Therefore, the process of precipitation should be paid more attention and water in the precipitation pools should be kept for a longer time. Also, the Coagulation process should be done more scientifically.

3:4 Calcium, Magnesium and TH

In general, the water body gains hardness as a result of the high presence of calcium and magnesium. Leaching of limestone, dolomite, magnesia and others lead to present high amounts of calcium and magnesium into the water body [15].

In the present study, the concentrations of Ca^{+2} are ranged between (11.32-14) mg/l. Also, the concentrations of Mg^{+2} are between (4.13-5.02) mg/l. Therefore, all the samples are within the acceptable limit based on the WHO standard [16].

TH values in intake and outlet point of Bardasoor Treatment Plant are within the acceptable levels in all the suburbs in Kalar. Also, the values of TH in all the suburbs are within acceptable levels; however, there is a slight increase in TH values in the suburbs compared to the intake and outlet point of Bardasoor Treatment Plant. Based on WHO standard, the permissible value of TH is (500) mg/l [16]. So, the quality of the water distribution pipes may have a role in this slight increase of TH values.

3:6 Iron & Fluoride

Normally, the acceptable concentration of iron should be less than (0.3) mg/l in drinking water; However, in some countries where iron salts are used in water-treatment plants as coagulating agents, Fe concentrations may be higher [17]. The results show that Fe concentrations in Kalars' suburbs are range between (0.11-0.18) ppm. Therefore, the values of Fe in all the stations in the present study were below the standard level.

Fluoride in water plays a significant role in the development of tooth enamel especially in children and in strengthening bones throughout life. It is recommended that the minimum permissible limit of fluoride in water should not be less than (1) mg/l [12]. Water sample analysis observed fluorides' values between (0.19 - 0.72) mg/l. The same problem indicates in intake and outlet points with the Bardasoor treatment plant. Therefore, the fluoridation process should be utilized to add portions of fluoride into the water before being distributed. Water fluoridation is the process that is done to adjust fluoride to public supply to reduce tooth decay. As well as it plays a role in rebuilding and strengthening the teeth surface

Water quality index (WQI)

Large numbers of water quality parameters are converted to a single indication or classification by using the Water quality index (WQI) tool. The classification includes: (excellent quality, good quality, poor quality, very poor quality, and unsuitable for drinking) to report the results easily to stakeholders and users [18]. The (WQI) classified water in Station O - intake WTP as (Very Poor Quality); however, it classified water in Station (Control/ output WTP) as (Good Quality), table (4) and figure (2). This indicates that the process of water treatment in Bardasoor WTP is correctly taking place. On the other side, the index classified water in Stations A and C as (Poor Quality) or unusable for drinking; on contrary, water in other stations was classified as (Good Quality) for the same purpose.

Table (4): Results of WQI and status

Sites	Index Value (WQI)	Status
O – Intake	79.36	Very poor quality
Control – Out-let	36.43	Good quality
A	53.15	Poor quality
B	48.51	Good quality
C	51.00	Poor quality
D	44.22	Good quality
E	39.46	Good quality
F	46.35	Good quality
G	45.73	Good quality
H	41.21	Good quality

Figure (2): WQI values at different sampling points

4 Conclusion and Recommendations

In this study, Water Quality Index (WQI) was assessed to determine water quality at different stations within the water distribution system in Kalar. The results show that WQI classified the water distribution system in Kalar as good to poor quality based on (WHO) standards.

As water moves away from the treatment plant in the pipes distribution system, pollutants could be presented as a result of breaks or leaking of pipes; thus, during the high pressure contaminated pool will be formed around leaking pipes, and during low-pressure pollutants may find their way into the distribution pipes. It is recommended that the water pipe distribution system must be maintained periodically to minimize the risk of pollution.

تقييم مؤشر جودة المياه (WQI) في شبكة توزيع المياه في كلار ، السليمانية ، العراق

الخلاصة

في هذا البحث، تم تقييم مؤشر جودة المياه (WQI) رياضيًا من أجل تحديد نوعية المياه في (محطة معالجة بردسور في قضاء كلار) وفي نقاط مختلفة داخل الأحياء السكنية، وعلى بعد مسافة من محطة المعالجة المذكورة للتحقق من جودة المياه في شبكة التوزيع. وقد تم جمع عينة ماء من نقطة الإدخال في محطة معالجة «بەردەسوور» قبل اجراء عملية المعالجة، وعينة أخرى بعد عملية المعالجة وقبل التوزيع. كما وتم جمع (٤٠)

عينـة مـن المياه في (٨) محطـات ضمـن الاحيـاء السـكنية وتـم إخضاعهـا لاختبـارات فيزيائية-كيميائيـة. وصنـف المـؤشر (WQI) جـودة المياه ضمـن نظـام توزيـع المياه في كلار عـلى أنهـا ذي (نوعيـة جيـدة) باسـتثناء (٢) محطتـين صنفتـا عـلى أنهـما ذات (نوعيـة رديئـة).

الكلـمات المفتاحيـة: محطـة معالجـة المياه (بەردەسـوور)، قضـاء كلار، جـودة المياه، مـؤشر جـودة المياه (WQI)، نظـام توزيـع المياه.

هەڵسـەنگاندنی پێـوەری کواڵیتـی ئـاو (WQI) لـە تـۆڕی دابەشـکردنی ئـاو لـە قـەزای کـەلار، سـلێمانی، عیـراق

پوختە

لـە ئـەم توێژینـەوەدا، هەڵسـەنگاندن کـرا بـۆ پێـوەری کواڵیتـی ئـاو کـە نـاسراوە بـە (WQI) بـە شـێوەی ماتماتیکـی بـە مەبەسـتی دیاریکـردنی جـۆری ئـاو لـە یەکـەی پاڵاوتنـی بەردەسـور لـە قـەزاری کـەلار، ولـە چەنـد وێسـتگەیەکی دیاریکـراو لـە نێـو گەڕەکـەکانی شـار، ولـە دوری چەنـد کێلۆمەترێـک لـە یەکـەی پاڵاوتنـی بەردەسـور. نمونەیەکـی ئـاو وەرگیـرا لـە خاڵـی (وەرگـر) پێـش پاڵاوتنـی، ونمونەیەکـی تـر وەرگیـرا دوای پاڵاوتنـی وپێـش دابەشـکردنی بـە سـەر هاوڵاتیانـدا، هەروەهـا (٤٠) نمونـە وەرگیـرا لـە شـوێنە جیـاوازەکانی نێـو گەڕەکـەکانی قـەزای کـەلار. هەمـوو نمونـەکان تێسـتیان بۆکـرا لـە رووی چەنـد پارامیتەرێکـی فیزیۆکیمیاویـەوە. بـە پێـی ئەنجامـەکان وبـە پشـت بەسـتن بـە پۆلێنـی کواڵێتـی ئـاو (WQI)، هەمـوو نمونـەکانی وێسـتگەکان لـە ئاسـتی (کواڵیتـی باش)دایـە جگـە لـە دوو وێسـتگە لـە کـە کواڵیتـی ئـاو تێیـدا لـە پۆلێنـی (کواڵیتـی خراپ)دایـە.

کلیلەووشـە: یەکـەی پاڵاوتنـی ئـاوی بەردەسـور، قـەزای کـەلار، جـۆری ئـاو، پێـوەری کواڵیتـی ئـاو، تـۆڕی دابەشـکردنی ئـاو

References

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[1]	R P Singh and P Mathur, “Investigation of variations in Physico-chemical characteristics of a freshwater reservoir of Ajmer city,” *Indian Journal of Environmental Sciences*, vol. 9, no. 1, pp. 57-61, 2005.
[2]	L Jin, P G Whitehead, G Bussi, F Hirpa, and M T Taye, “Natural and anthropogenic sources of salinity in the Awash River and Lake Beseka (Ethiopia): Modelling impacts of climate change and lake-river interactions,” *Journal of Hydrology: Regional Studies*, vol. 36, no. 1, p. 100865, 2021.
[3]	R A Ainsworth, “Water quality changes in the piped distribution system,” World Health Organization, 2002.
[4]	J K Clark, “The Presence- Absence test for monitoring drinking water quality,” in *Drinking Water Microbiology*. New York, NY: Springer, 1990, pp. 399-411.

[5]	RZardawy Sarhat Abdulmutalib, "THE ISSUE OF IGNORING SIRWAN RIVER WITH THE EXCESSIVE USE OF GROUNDWATER IN KALAR CITY," *IRAQI JOURNAL OF DESERT STUDIES*, vol. 5, no. 1, 2013.
[6]	American Public Health Association (APHA), "American public health association. standard methods for the examination of water and wastewater," Water Environmental Federation, Washington, 2005.
[7]	World Health Organization, "A global overview of national regulations and standards for drinking-water quality," World Health Organization, 2021.
[8]	R M Brown, N I McClelland, R A Deininger, and M F O'Connor, "A water quality index—crashing the psychological barrier," in *Indicators of environmental quality*. Boston, MA: Springer, 1972, pp. 173-182.
[9]	C Chatterjee and M Raziuddin, "Determination of Water Quality Index(WQI) of a degraded river in Asansol industrial area(West Bengal)," *Nature, Environment and pollution technology*, vol. 2, no. 1, pp. 181-189, 2002.
[10]	A Pruss-Ustun and C F Corvalán, "Preventing disease through healthy environments: towards an estimate of the environmental burden of disease," World Health Organization, 2006.
[11]	T A Bauder, R M Waskom, P L Sutherland, and J G Davis, *Irrigation water quality criteria*. Colorado: Colorado State University, 2011.
[12]	WHO, *Guidelines for drinking-water quality*, 4th ed. 104-108: WHO chronicle, 2011.
[13]	M Mohsin, S Safdar, F Asghar, and F Jamal, "Assessment of drinking water quality and its impact on residents health in Bahawalpur City," *International Journal of Humanities and Social Science*, vol. 3, no. 15, pp. 114-128, 2013.
[14]	A Tessema, A Mohammed, T Birhanu, and T Negu, "Assessment of Physico-chemical water quality of Bira dam, Bati Wereda, Amhara region, Ethiopia," *Journal of Aquaculture Research and Development*, vol. 5, no. 6, 2014.
[15]	P K Gupta and P K Gupta, *Methods in environmental analysis: water, soil and air*. Jodhpur, India: Agrobios, 2007.
[16]	H Galal-Gorchev and G Ozolins, "WHO guidelines for drinking-water quality," *Water supply*, vol. 11, no. 3, pp. 1-16, 1993.
[17]	World Health Organization, "Iron in drinking-water. WHO Guidelines for drinking-water quality," WHO, Backgr. Doc. Dev. WHO Guidel, 2003.
[18]	H Boyacioglu, "Utilization of the water quality index method as a classification tool," *Environmental monitoring and assessment*, vol. 167, no. 1, pp. 115-124, 2010.
[19]	W Zhang et al., "Effects of physical-biochemical coupling processes on the Noctiluca scintillans and Mesodinium red tides in October 2019 in the Yantai nearshore, China," *Marine Pollution Bulletin*, vol. 160, p. 111609, 2019.
[20]	M Zhou, T Yan, and J Zhou, "Preliminary analysis of the characteristics of red tide areas in Changjiang River estuary and its adjacent sea," *Ying Yong sheng Tai Xue bao= The journal of applied ecology*, vol. 14, no. 7, pp. 1031-1038, 2013.
[21]	K Aoki et al., "Increased occurrence of red-tides of fish-killing dinoflagellate Karenia Mikimoto and related environmental conditions in Imari Bay, Japan," *Regional Studies in Marine Science*, vol. 1, no. 39, p. 101470, 2020.

[22]	ELAINA ZACHOS. (2016, August) National Geographic. [Online]. https://www.nationalgeographic.com/science/article/why-giant-green-lake-turned-blood-red-iran-algae
[23]	H J Jeong et al., "Raphidophyte red tides in Korean waters," *Harmful algae*, vol. 1, no. 30, pp. S41-S52, 2013.
[24]	Arpan Rai. (2021, September) independent. [Online]. https://www.independent.co.uk/news/world/middle-east/dead-sea-turn-red-lake-motro-b1919605.html?utm_source=ground.news&utm_medium=referral
[25]	A R Sarhat, A H Alshatteri, and H J Nori, "Assessment of Physicochemical Properties of Water in Bawashaswar Dam, Kurdistan Region, Iraq," *Diyala Journal For Pure Science*, vol. 14, no. 4, 2018.
[26]	Water Environmental Federation, "American public health association. standard methods for the examination of water and wastewater," American Public Health Association (APHA), Washington, 2005.
[27]	R M Brown, N I McClelland, R A Deininger, and M F O'Connor, "A water quality index—crashing the psychological barrier," in *Indicators of environmental quality*. Boston: Springer, 1972.
[28]	C Chatterjee and M Raziuddin, "Determination of Water Quality Index(WQI) of a degraded river in Asansol industrial area(West Bengal)," *Nature, Environment and pollution technology*, vol. 1, no. 2, pp. 181-189, 2002.
[29]	Abdulmutalib Raafat Sarhat, "Assessment of groundwater quality and its suitability for agricultural uses in Kifri," *Journal of Garmian University*, vol. 4, no. 1, 2017.
[30]	A Prüss-Üstün, J Wolf, C Corvalán, R Bos, and M Neira, *Preventing disease through healthy environments: a global assessment of the burden of disease from environmental risks.*: World Health Organization, 2016.
[31]	S N Yeroyan, S M Mkrtchyan, M A Kalantaryan, and A G Naghdalyan, "ASSESSMENT OF UNDERGROUND AND SURFACE WATER BY IRRIGATION WATER QUALITY STANDARDS," *Известия высоких технологий*, vol. 2, no. 1, pp. 27-32, 2016.
[32]	N Troudi, F Hamzaoui-Azaza, O Tzoraki, F Melki, and M Zammouri, "Assessment of groundwater quality for drinking purpose with special emphasis on salinity and nitrate contamination in the shallow aquifer of Guenniche (Northern Tunisia)," *Environmental Monitoring and Assessment*, vol. 192, no. 10, pp. 1-19, 2020.
[33]	World Health Organization (WHO), *A global overview of national regulations and standards for drinking-water quality.*, 2021.
[34]	A Colter and R L Mahler, "Iron in drinking water," Moscow.
[35]	World Health Organization (WHO), *Calcium and magnesium in drinking water: public health significance.*: World Health Organization, 2009.
[36]	World Health Organization (WHO), "Hardness in drinking-water: Background document for development of WHO guidelines for drinking-water quality," World Health Organization, No. WHO/HSE/WSH/10.01/10, 2010.
[37]	M T Bashir, S A Ali, and A D Bashir, "Health effects from exposure to sulphates and chlorides in drinking water," *Pakistan J. of medical and health sciences*, vol. 3, 2012.

[38]	Akeel M. Kadim and Wasan Rashid Saleh, "Morphological and Optical Properties of CdS Quantum Dots Synthesized with Different pH values," *Iraqi Journal of Science*, vol. 58, no. 3A, pp. 1207-1213, 2017.
[39]	Qingful Zhang and Hui Li, "MOEA/D: A Multiobjective Evolutionary Algorithm Based on Decomposition," *IEEE Transactions on Evolutionary Computation*, vol. 11, no. 6, pp. 712-731, 2007.
[40]	Simone Romano, James Baily, Vinh Nguyen, and Karin Verspoor, "Standardized Mutual Information for Clustering Comparisons: One Step Further in Adjustment for Chance," in *Proceedings of the 31st International Conference on Machine Learning*, vol. 32, Beijing, 2014, pp. 1143-1151.
[41]	Jason Brownlee, *Clever Algorithms: Nature-Inspired Programming Recipes*. Australia: LuLu Enterprise, 2011.
[42]	Home Office. Animals (Scientific Procedures), "Code of Practice for the Housing and Care of Animals Used in Scientific Procedures.," Act 1986.
[43]	Committee on Publication Ethics (COPE), "Code of Conduct and Best-Practice Guidelines for Journal Editors," 2011.
[44]	H Gebru and J Ahmed, "Water quality assessments as an implication to human health: A case study in awash sebat and its surrounding areas, Afar, Ethiopia," *International Journal of Earth Sciences and Engineering*, vol. 9, no. 5, pp. 1999-2008, 2016.

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