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VALIDATING RIVER BANK FILTRATION APPLICABILITY IN IRAQ AGAINST INTERNATIONAL STANDARDS

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Abstract: In the framework of assessing the applicability of RBF "***R***iver ***B***ank ***F***iltration" technique in Iraq, this research was originated in order to validate its applicability against International Standards, where CCME-WQI "***C***anadian ***C***ouncil of ***M***inisters of the ***E***nvironment ***W***ater ***Q***uality ***I***ndex" was selected. A previous research results were adopted [1]. Principally, literature was reviewed in the field of RBF applicability verification. The results of the previous research were implemented to calculate the Canadian index, where 17 parameters were selected. These were Turbidity, No_2 , So_4 , TDS, F, NH_3 , Cl, Fe, Res cl, pH, DO, Alkalinity ($Caco_3$), Total Hardness ($Caco_3$), Ca, Mg, Mn and No_3. Results were obtained; analyzed and plotted on graphs. From the graphs, apparent was that the WQI values ranged between 87 and 100, which indicated that the WQ "***W***ater ***Q***uality" is within the acceptable range of the Canadian Standards that ranked the water quality, as "Excellent". Confident with the validation of RBF applicability, it was further recommended to inspect its sustainability.

Keywords: River bank Filtration (RBF), Tigris River, Water Scarcity, water conflict, Iraq, CCME-WQI.

1. INTRODUCTION

Tigris River is the major water supply to Iraq. Accordingly, it is the cradle of its civilization. Recently, Iraq is confronted with water scarcity challenges due to its high population growth rates, where its annual freshwater is 1000 m^3/capita, according to WBCSD "***W***orld ***B***usiness ***C***ouncil for ***S***ustainable ***D***evelopment". Moreover, 10% of its household reports, daily, water supplies problems, in terms of unsafe drinking water sources. In addition, water supply and sanitation are characterized by poor service quality. Accordingly, new techniques were due to be introduced to Iraq to contribute in confronting the challenges. Accordingly, this research was initiated to validate RBF application in Iraq, after its applicability was verified by [1].

In terms of the importance of the Canadian Index due to its worldwide applications, which is important for all environmental agencies, it was implemented regularly in detecting rivers and streams WQ. This is accredited to counting it as a global index that is implemented for multi-purposes, according to the selected parameters.

Consequently, WQI was employed in Egypt; figure (1). Among these employments were, for example [2] who utilized this index to inspect EL-Salam Canal so as the Nile River WQ, in terms of drinking, irrigation, livestock and aquatic life. Likewise [3] employed this index to evaluate WQ of the main irrigation canals and drains, in Upper Egypt, during 2001-2004. Similarly [4] used the Canadian Index to assess EL-Salam Canal, at 4 measuring locations, where the index rank was between "fair" and "good", in terms of irrigation use. In addition [5] banked on the Canadian Index to signpost Western delta canals WQ, within Egyptian standards of the law of 48/1982.

On the other hand [6] deliberated the Canadian Index, to judge Mahmoudia Canal WQ at different positions, where he carried a sampling campaign to extract 122 water samples, from 11th of June till 12th of May. His results accredited the canal pollution to Zircon Drain discharges. He further attributed the pollution of Rosetta branch to El-

Rahawy Drain. Moreover [7] tooled the Canadian Index to inspect Nile River WQ, in terms of drinking so as aquatic life requirements. They selected 17 WQ parameters to calculate this index. Based on 24 sampling points results, distributed along Cairo to Aswan, they designated that the index was ranked, as "good". This was in terms of drinking purposes, while the index was scored, as "poor" for aquatic life.

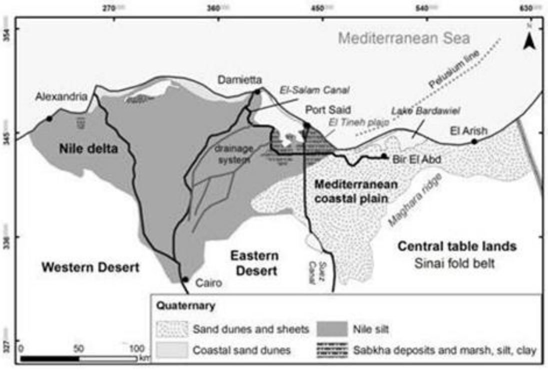


Fig (1) WQI applications in Egypt

2. METHDOLOGY

Water quality parameters are designated by ***CCME-WQI*** "***C***anadian ***C***ouncil of ***M***inisters of ***E***nvironment ***WQ*** ***I***ndex", where the index is a value that encompasses several parameters that are interpreted by the decision-makers.

In the 1990ies, ***CCME*** introduced a ***WQI*** that was proposed by the "WQ Guidelines Task Group", which was driven by ***BCWQI*** "***B***ritish ***C***olumbia ***WQ I***ndex".

The Canadian index was tooled in this research, as it is worldwide acknowledged and is of significance to environmental agencies, where its indices describe rivers so as streams WQ. In addition, based on the selected parameters, it is utilized as a global guide to multi-purposes.

However, the Canadian index is not linear. Nevertheless, the Canadian Index concept relies on the sampling frequency so as its nonconformity from the variables authorized value, where WQI depends on 3 factors. These are F_1, F_2, F_3. They are ranked from 0 to 100; figure (2).

- F_1 is a factor representing the scope. It is a guideline for nonconformity during sampling duration. It links number of failed variables that are not within the guidelines; equation (1).
- F_2 is a factor that designates the frequency. It links the failed tests number to the variables that do not meet the guidelines to the total number of measurements; equation (2).
- F_3 denotes amplitude. It characterizes how distant the failed measurements from the requirements; equation (6).

F_3 is calculated via three steps, as follows:

- ***1st Step:*** Calculate the frequency of deviating from the standard guidelines, where the objective is labeled as "excursion", in the case of exceeding maximum standard guidelines value and in case of attaining the minimum standards; equations (3) and (4), respectively.
- ***2nd Step:*** The term "nse" is calculated by relating individual to total tests number; equation (5).
- ***3rd Step:*** F_3 is obtained by implementing equation (6).

After substituting in equations (1) till (6), equation (7) is tooled to calculate the Index WQI. However, table (1) is provided to list the corresponding scores of the index.

$$F_1 = \left(\frac{\textbf{number of failed variables}}{\textbf{total number of variables}}\right) * 100 \qquad (1)$$

$$F_2 = \left(\frac{\textbf{number of failed tests}}{\textbf{total number of tests}}\right) *100 \qquad (2)$$

$$Excursion_i = \left(\frac{\text{failed test value}_i}{\text{Objective}_j}\right) - 1 \qquad (3)$$

$$Excursion_i = \left(\frac{Objective_j}{failed\ test\ value_i}\right) - 1 \qquad (4)$$

$$nse = \sum_{i=1}^{n} \frac{excursion_i}{no.\ of\ tests} \qquad (5)$$

$$F_3 = \left(\frac{\boldsymbol{nse}}{\mathbf{0.01}\ \boldsymbol{nse} + \mathbf{0.01}}\right) \qquad (6)$$

$$WQI = 100 - \left(\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}\right) \qquad (7)$$

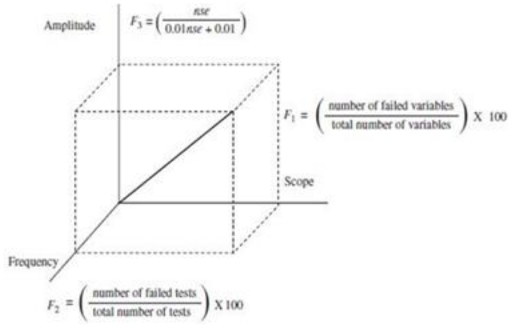


Fig (2) CCME-WQI relations

Table (1) WQI ratings or scores

CCME – WQI Value	Rating	Notes
95 to 100	Excellent	Water quality is protected against impairment absence.
80 to 94	Good	Water quality is protected by minor impairment degree.
65 to 79	Fair	Water quality is occasionally protected but impaired.
45 to 64	Marginal	Water quality is frequently vulnerable.
0.0 to 44	Poor	Water quality is weakened.

EMPLOYING THE CANADIAN INDEX "WQI"

CI "***C***anadian ***I***ndex" was tooled in this research to validate the results of [1]. This is attributed to the fact that CI is important for environmental agencies that detect WQ of rivers and streams. In addition, it was employed, as it is applicable for multi-purposes, in terms of the selected parameters.

IMPLEMENTED WATER QUALITY DATA

[1] selected a study area along the left bank of Tigris River; figure (3). They bored boreholes to provide an insight to the stratification of the soil figure (4).

They drilled 24 wells during a sampling campaign in November 2021 in the study area. The wells were along 4 lines, at Tigris River Left Bank, right angled to its centerline. The well lines were at 110.0, 110.5, 111 and 111.5 km apart of Mousel Dam. On each line, there were 4-near wells and 2 far-wells; figure (5). The 4 near-wells that were drilled at 5, 10, 15 and 20 m, while the 2 far-wells were drilled at 100 and 200 m, away from Tigris Bank. They extracted 28 samples from 16 near-wells, 8 far-wells and 4 Tigris River.

These samples were analyzed in Kirkuk Agriculture Directorate Laboratory Department to detect 23 water quality parameters and 644 results were obtained, where the 644 results are the multiplication of 28 samples by 23 parameters.

Fig (3) Study area map

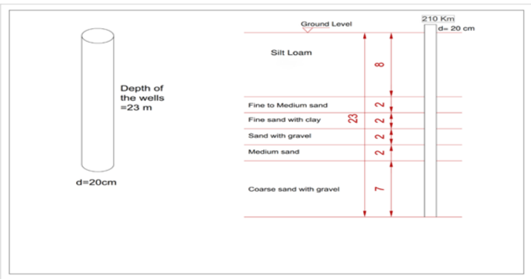


Fig (4) Soil stratification in the study area

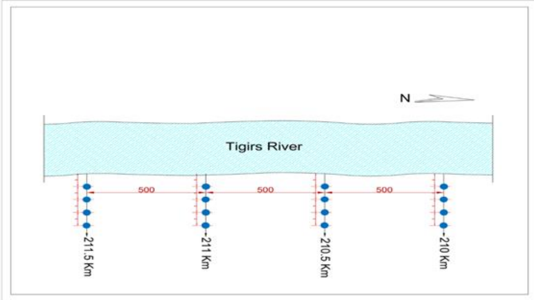


Fig (5) The drilled near-wells

3. NOMINATING PARAMETERS FOR WQI DESIGNATION

Selecting WQ parameters for attaining WQI is a process of great significance. Accordingly, only 17 parameters of the 23 investigated parameters of [1] were nominated to be implemented in the present research.

This means that only 476 readings were adopted from their results, where the 476 results are the multiplication of 28 samples by 17 parameters.

They were selected, as indicators to agriculture, industrial, organic and domestic pollution. They encompassed Turbidity, No_2 , So_4 , TDS, F, NH_3 , Cl, Fe, Res cl, pH, DO, Alkalinity ($Caco_3$), Total Hardness ($Caco_3$), Ca, Mg, Mn and No_3. Table (2) lists the nominated parameters so as their guidelines, in terms of Iraqi's guidelines for drinking purposes.

Table (2) Nominated parameters for WQI calculations and Iraqi's Standards

No.	Parameter	unit	Iraqi Standard (417/2001)
1	pH	-	7-8.5
2	Turbidity	NTU	5 unit
3	T.D.S.	mg/l	500
4	Alkalinity as caco3	mg/l	200
5	Total Hardness as caco3	mg/l	500
6	Calcium	mg/l	50
7	Magnesium	mg/l	50
8	Chloride	mg/l	200
9	Sulfate as so4	mg/l	200
10	Ammonia as NH3	mg/l	0.20
11	Nitrite as No2	mg/l	3
12	Nitrate No3	mg/l	40
13	Iron Fe	mg/l	0.3
14	Manganese	mg/l	0.1
15	Residual Chlorine	mg/l	0.5
16	D O	mg/l	>5
17	Fluoride	mg/l	1

4. WQI COMPUTATION

In this study, these 476 readings were implemented and WQI was computed, where this was achieved by tooling the 17 selected parameters results.

In order to achieve this, equations (1) through (7) were implemented, where the Canadian Index was calculated based on the 476 laboratory results of Kirkuk Agriculture Directorate Laboratory Department.

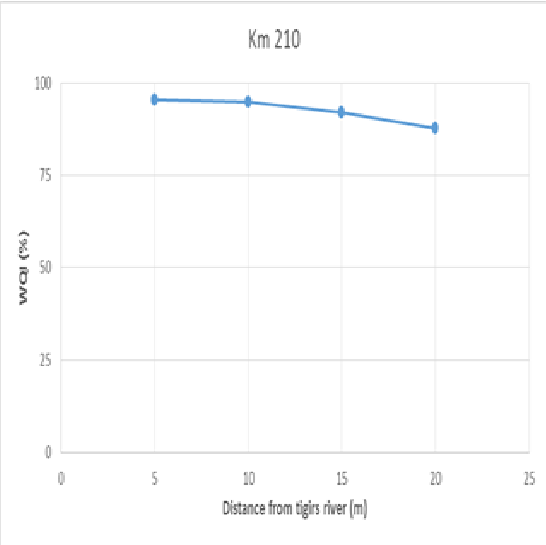
5. RESULTS ANALYSIS AND DISCUSSION

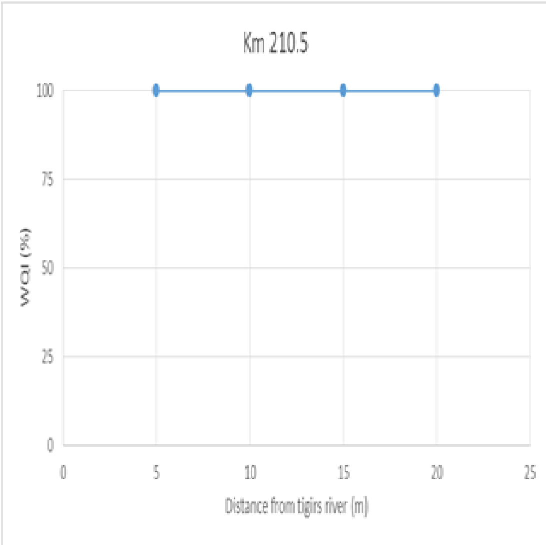
The estimated WQI values were plotted on Figures (5) to (7), where Figure (5) present the calculated WQI values for the ***near-wells*** at 210.0, 210.5, 211.0 and 211.5 km, respectively.

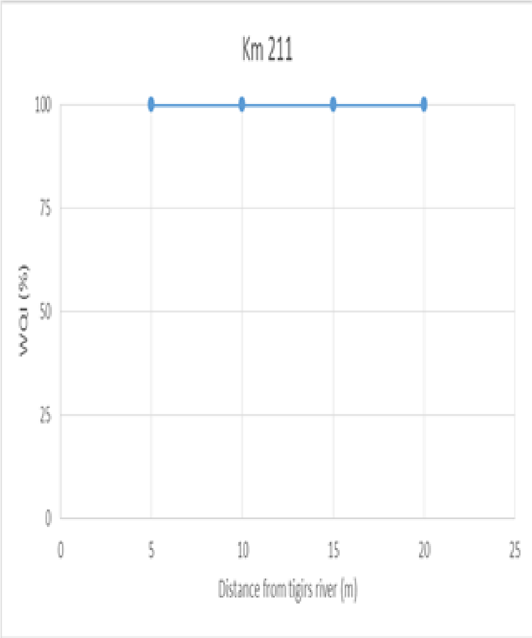
On the other hand, figures (6) and (7) represent the calculated WQI values for the ***far-wells*** and ***Tigris River***, respectively. In addition, a summary to the results is listed in table (3).

Based on the WQI calculations, apparent was the following:

- Regarding the ***near-wells*** samples, the WQI values ranged between 87 and 100.
- The ***near-wells*** samples indicated that the water quality is within the acceptable range and is ranked as "Excellent".
- As for the ***far-wells*** samples, the WQI values ranged between 39 and 46.
- The ***far-wells*** samples indicated that the water quality is beneath the acceptable range and is ranked as "Marginal to Poor".
- Concerning the ***Tigris River*** samples, the WQI values ranged between 88 and 90.
- The ***Tigris River*** samples indicated that the water quality is within the acceptable range and is ranked as "Good".







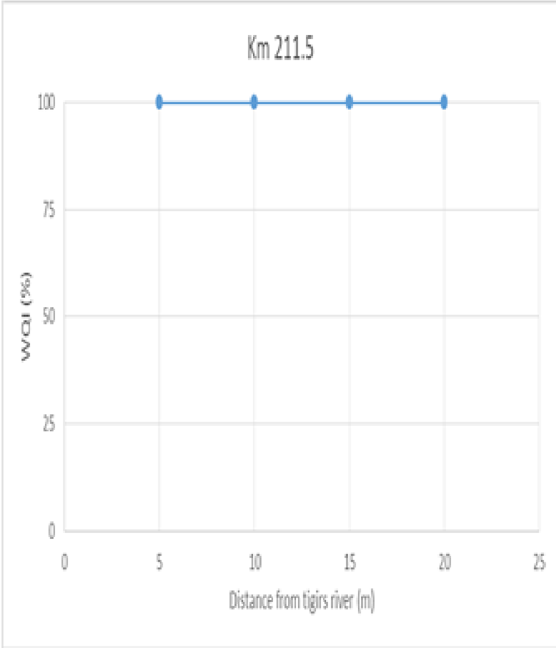


Fig (5) *WQI* of near wells

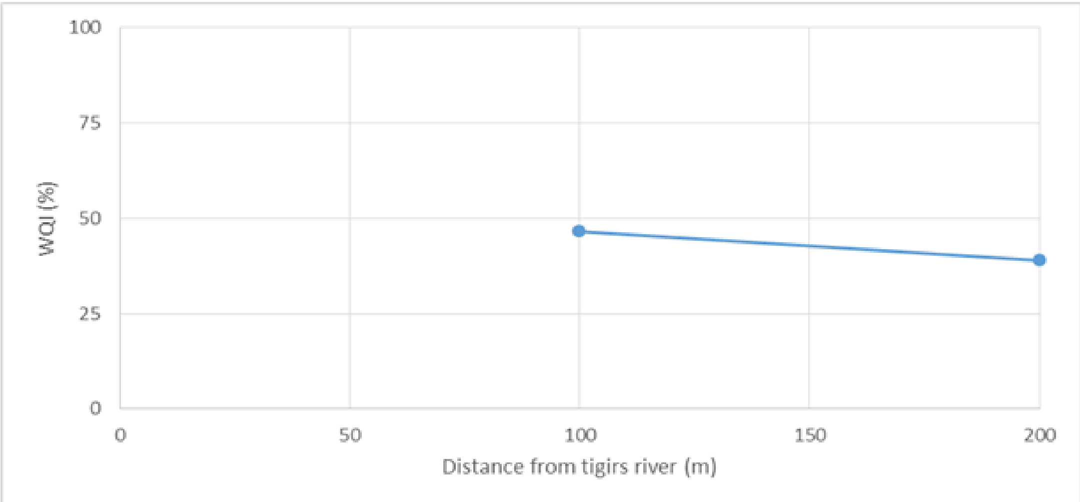


Fig (6) Average values of WQI for far wells

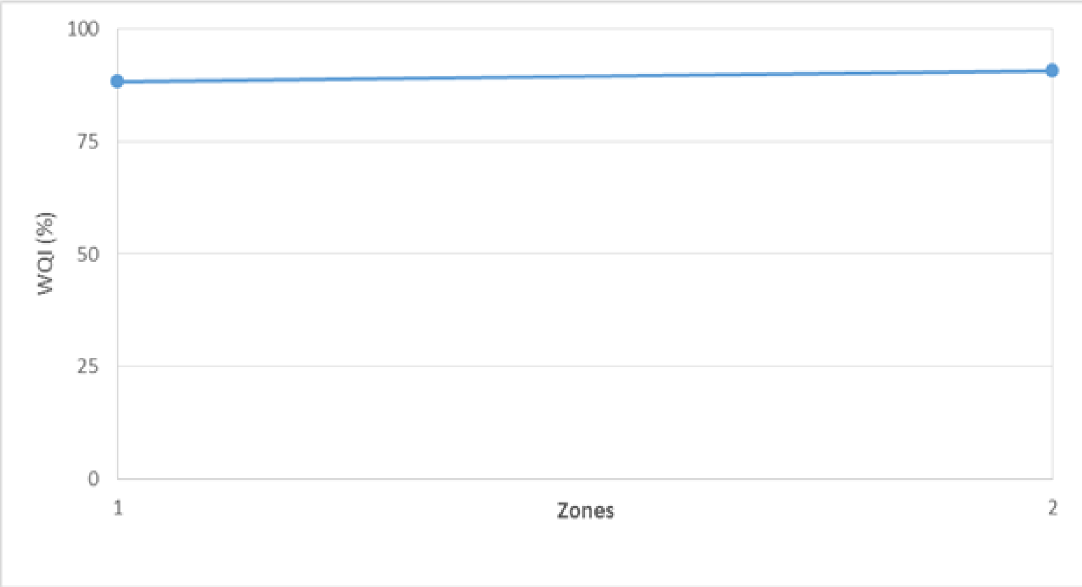


Fig (7) Average values of WQI for Tigris River

Table (3) WQI for near-wells, far-wells and Tigris

Site	Distance from RB	No. of Varibles	Failed Variables	No of Tests	Failed Tests	F_1	F_2	Sum of Excursions	nse	F_3	WQI	Rank
Near-well 210 km	5	17	1	102	1	5.88	0.98	6.04	0.06	5.59	95.28	Excellent
	10	17	1	102	1	5.88	0.98	7.47	0.07	6.83	94.7	Good
	15	17	1	102	1	5.88	0.98	14.15	0.14	12.18	92.17	Good
	20	17	2	102	2	11.76	1.96	21.74	0.21	17.57	87.7	Good
Near-well 210.5 km	5	17	0	102	0	0	0	0	0	0	100	Excellent
	10	17	0	102	0	0	0	0	0	0	100	Excellent
	15	17	0	102	0	0	0	0	0	0	100	Excellent
	20	17	0	102	0	0	0	0	0	0	100	Excellent
Near-well 211 km	5	17	0	102	0	0	0	0	0	0	100	Excellent
	10	17	0	102	0	0	0	0	0	0	100	Excellent
	15	17	0	102	0	0	0	0	0	0	100	Excellent
	20	17	0	102	0	0	0	0	0	0	100	Excellent
Near-well 211.5 km	5	17	0	102	0	0	0	0	0	0	100	Excellent
	10	17	1	102	1	5.88	0.98	0.13	0	0.13	96.56	Excellent
	15	17	1	102	1	5.88	0.98	0.43	0	0.42	96.55	Excellent
	20	17	1	102	1	5.88	0.98	0.77	0.01	0.75	96.53	Excellent

Site	Distance from RB	No. of Varibles	Failed Variables	No of Tests	Failed Tests	F_1	F_2	Sum of Excursions	nse	F_3	WQI	Rank
Far-well 100 m from RB		17	10	102	58	58.82	56.68	76.5	0.75	43	46.6	Marginal
Far-well 200 m from RB		17	12	102	64	70.59	62.75	89.76	0.88	46.86	39.13	Poor
Tigirs		17	3	102	8	17.65	7.84	6.12	0.06	5.76	88.36	Good
Tigirs		17	2	102	8	11.76	7.84	8.16	0.08	7.36	90.8	Good

6. CONCLUSIONS AND RECOMMENDATIONS

Based on the research results, the deduced conclusions were, as follows:

- RBF applicability is validated against International Standards.
- The WQI value for the ***near-wells*** samples varied between 87 and 100, which indicated that RBF applicability is validated against International Standards, as ***near-wells*** samples were ranked as "Excellent" and does not need any treatment.
- The WQI value for the ***far-wells*** samples varied between 39 and 46, which indicated that RBF applicability is not validated against International Standards for the groundwater, as the ***far-wells*** samples were ranked as "Marginal to Poor".
- The WQI value for the ***Tigris River*** samples varied between 88 and 90, which signposted that its water is not validated against International Standards, as it is ranked as "Good". Accordingly, it needs partial treatment.
- RBF is an amazing technique, as it is a pretreatment membrane filtration.
- RBF diminishes the treatment cost.
- RBF meets the pathogens regulations.
- RBF disinfects byproducts and contaminants.
- RBF filtrates water regardless to river condition.
- RBF designed systems serve as pretreatment for drinking water

Based on the research conclusions, the suggested recommendations were, as follows:

- Employ RBF in Iraq, as it is acceptable for drinking use without any treatment and is validated against International Standards of CCME-WQI.
- Implement RBF, as it is an innovative reliable source of drinking water technique to confront water crisis facing Iraq.
- Investigate RBF sustainability in Iraq.

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