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Investigation of Boron Concentrations in the Water of Rivers and Wells in Northern Regions of Thi-Qar Province Using SSNTDs Technique

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***Abstract*— The Iraqi environment is polluted, especially in the southern region, due to human domestic activities, such as sewage water containing boron due to washing powders that boron participates in producing, which are not connected to sewage networks and are poured into the river water, in addition to industrial facilities and farmers' use of fertilizers that contain boron, which also contributed effectively to increasing the concentration of boron, as the work areas work specifically to monitor minerals in the water sample, which is essential to controlling the human environment in the north of Thi-Qar Governorate. In this study, 31 colors of Nahr Bar water were collected, and boron concentrations were measured using SSNTDs CR39 technology and the 241Am-Be neutron beam station. Selected water samples were taken from different waters–and from water sources and the Euphrates River in various residential, agricultural and industrial sites. Boron concentrations in well water from 1.94 to 3.63 mg/L, while boron levels in river water ranged from 1.85 to 2.34 mg/L. Boron levels in well water were higher than those in river water samples. Boron concentrations in agricultural sites were higher than in industrial and residential sites. Boron levels in most water samples were below the required levels set by the US Environmental Protection Agency and the World Health Organization. However, monitoring water to prevent contamination from affecting the human chain is important.**

***Keywords*— However, monitoring water to prevent contamination from affecting the human chain is important.**

I. Introduction

Boron is an elemental substance that may present in rock, soil, and water. It belongs to the non-metal group of elements. The element has an atomic number of 5 and a weight of 10.81 atomic mass units. Boron consists of two isotopes: boron-10 with a relative abundance of 19.8%, and boron-11 , with the relative abundance of 80.2% [1] .Water consumption is vital to life. However, water can pose health risks if the natural quality of drinking water is not maintained [2]. Recent years have witnessed many fascinating advances in the field of boron research, which have greatly improved our knowledge about the function of boron in plants [3]. The World Health Organization issues international standards on water quality and human health in the form of guidelines that are used as a basis for regulation and standard setting around the world [4]. The Office of Water (OW) sponsors the Health Advisory (HA) Program, which publishes data on the characteristics of drinking water contaminants, both regulated and unregulated, including their effects on health, environmental factors, analytical techniques, and remediation techniques. HAs have non-regulated amounts of contaminants present in drinking water that are not expected to manifest negative health consequences over a range of exposure times (one day, ten days, several years, and a lifetime). HAs are informal technical guidelines that help managers of public or community water systems, and officials protect public health in the event of contamination or emergency spills. They should not be construed as legally binding federal standards. HAs can change as additional information becomes available [5]. With an oxidation state of +3, boron is a non-metallic element found in group IIIA of the periodic table. It has an atomic weight of 10.81 and an atomic number of 5. 10B (19.8%) and 11B (80.2%) are the two stable isotopes of boron [6]. Boron is one of the natural elements found in water and the Earth's crust whose concentration

Exceed 100 parts per million (100 ppm) Typically, boron concentration is less than 10 ppm [7]. It is found on Earth not as an element but in the forms of borax, boric acid, tourmaline, colemanite, kern it, ulexite, and borates [8]. It is mostly found in aqueous solutions with pH values below 7. The tetrahedral borate anion is generated at high pH levels when undissociated boric acid (H_3BO_3) absorbs hydroxyl ions from water [9]. A high prevalence of boron deficiency is seen in crops grown with high pH, low levels of organic matter, and high free carbon [10]. Drugs, cosmetics, and mild disinfectants that can be released into the environment include boric acid, borates, and borates [11]. The production of glass, soap, detergents, flame retardants, and nuclear power plants involves boric acid and borates, which may cause boron poisoning in the surrounding environment. Because borates are less insect-resistant than organic pesticides and are not carcinogenic, they are frequently used in agriculture as fertilizers, insecticides, and herbicides [12]. Boron silicate is found in igneous, metamorphic, and sedimentary rocks–and is resistant to weathering, making it inaccessible to plants [13]. It is naturally stable. Two types

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of boron are found in solution: tetrahedral borate anion $B(OH)_4$ and trigonal boric acid $B(OH)_3$ [14]. Figure (1) shows the chemical structure of many boron compounds.

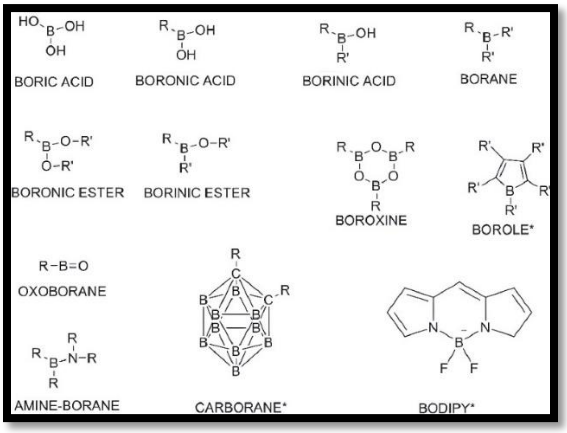

Fig. 1: Chemical structures of boron compounds [15].

The production of glass, soaps, cleaning powder, flame retardants, and neutron absorbers for nuclear sites using boric acid and borates may cause boron toxicity in the environment. Borates are used in agriculture, among other things, as fertilizer [16]. Insecticide and herbicide as opposed to organic pesticides since they lack insect resistance and are not hazardous to mammals When igneous, metamorphic, sedimentary rocks are exposed to extreme temperatures, boron is present as borosilicate and is not accessible to plants [17]. Elemental boron cannot be dissolved in water Borax (dry) does not have a boiling point. Borax decomposes at 75°C. It loses $5H_2O$ at 100°C, and $9H_2O$ at 150°C. It turns anhydrous at 320°C. Dissolution The point of anhydrous borax is above 700°C and decomposes at 1575°C [18]. The study aims to

determine the concentration of boron present in he the water of the studied area to calculate the boron levels in ordinary water and know the extent of its health effect.

II. Materials and Methods

A. Study Area

The study area was conducted in Thi Qar Governorate, which is located in the southern part of Iraq, between latitudes (29.5° and 31.5°) north and longitudes (46.4° and 47.65°). Its capital is the city of Nasiriyah. The study included the northern regions of the governorate Al-Shatrah and Al-Gharraf) . Figure (2) shows the study sites in these cities.

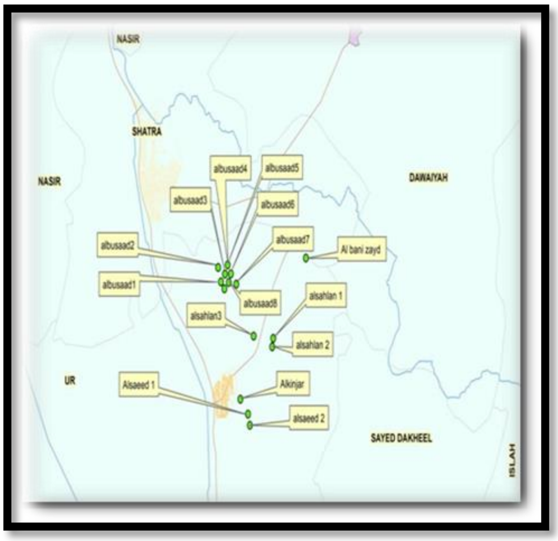

Fig. 2: Map of the study sites.

B. Samples Collection and Preparation

In this study, 31 rivers and well water samples were collected in the northern regions of Thi-Qar Governorate. The collection mechanism consisted of two river stations (Al-Shatra and Al-Gharraf) and 15 stations distributed in Al-Sahlan, Al-Busad, Bani Zaid, Al-Khanjar, and Al-Bu Said. Solid nuclear track detectors (SSNTDs) have been used to test river and well water boron concentrations

Water samples from SSNTD and CR-39 (1.5 x 1.5 x 0.5) *cm* films are available from several locations. For every 1 ml of water, the sample is placed in the same location as the CR-39 track detector, as in Figure (3), and left to dry. After drying, the samples were exposed to a thermal neutron source (^{241}Am-Be) for seven days, and to a thermal neutron source.

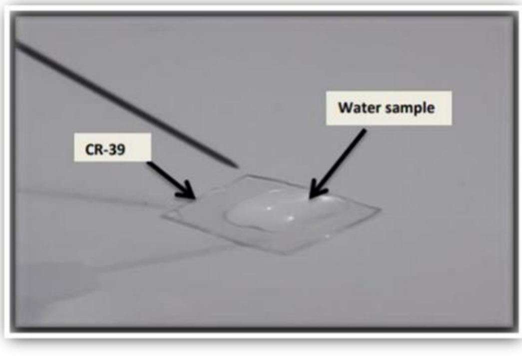

Fig. 3: Preparation of samples to irradiation (water drops on the CR-39 detector

C. Samples Irradiation

The water samples from the river, encapsulated in pellet form, are encased with CR-39 detectors and arranged on a paraffin wax plate. This assembly is placed 5 cm away from a neutron source, specifically an ^{241}Americium-Beryllium (^{241}Am-Be) emitter. The Am-Be source is utilized for its stable emission of thermal neutrons, with a flux measured at $\mathbf{6.2 \times 10^{6} ncm^{-2} s^{-1}}$. This setup is illustrated in Figure (4). The strategic positioning and shielding are critical in ensuring the neutrons effectively interact with the samples, allowing for precise boron concentration measurements via the CR-39 detectors. Such meticulous setup is imperative to achieve accurate and repeatable results from the analysis of the well water samples.

$$ {}^{9}_{4}\mathbf{Be} + {}^{4}_{2}\mathbf{He} \rightarrow {}^{12}_{6}\mathbf{C} + {}^{1}_{0}\mathbf{n} + \mathbf{5.76 MeV} \; \ldots\ldots\ldots. \quad (\mathbf{1}) $$

Fig. 4: ^{241}Am-Be neutron irradiation station

Equation (2) also shows thermal neutron bombardment of the element boron. The reaction ^{10}B (n, α) ^{7} Li occurred:

$$ {}^{10}_{5}\mathbf{B} + {}^{1}_{0}\mathbf{n} \rightarrow {}^{7}_{3}\mathbf{li} + {}^{4}_{2}\mathbf{He} + \mathbf{2.31\ MeV} \text{----------------} (2) $$

producing alpha particles with an energy of 2.31 MeV. These particles can produce an acceptable track in the CR-39 plastic detector. After exposure, samples are rinsed with distilled water and then etched in the solution.

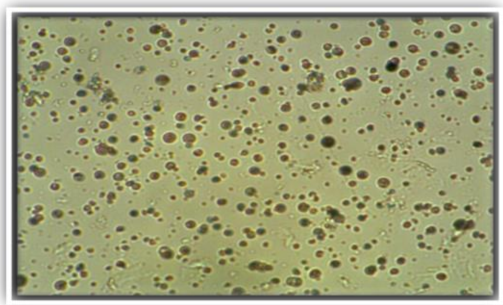

Fig. 5: Image of the α-particles track in the CR-39 detector.

D. Chemical Etching and Scanning Using a Microscope

After exposure to radioactivity for seven days, the nuclear reaction formula below was used to explain the irradiation process performed on the samples, which is as follows:

$$ 10_{B} + 1_{n} \rightarrow 11_{B} \rightarrow 7_{Li} + 4_{He} + 2.79\ MeV \text{-----}(3) $$

$$ 10_{B} + 1_{n} \rightarrow 11_{B} \rightarrow 7_{Li} + 4_{He} + 2.31\ MeV \text{-----}(4) $$

CR-39 reagents were extracted and subjected to chemical etching in a (6.25 M) NaOH aqueous solution, maintained at 60 °C for a standard period of 6 h, as described by Singh et al. (2001) [19]. After etching, the detectors are rinsed well with distilled water and left to air dry. The formation of distinct tracks on the CR-39 detectors was carefully documented using a Micros digital computerized optical microscope from Austria with 40x magnification shown in Figure (5).

Fig. 6: Micros digital computerized optical microscope

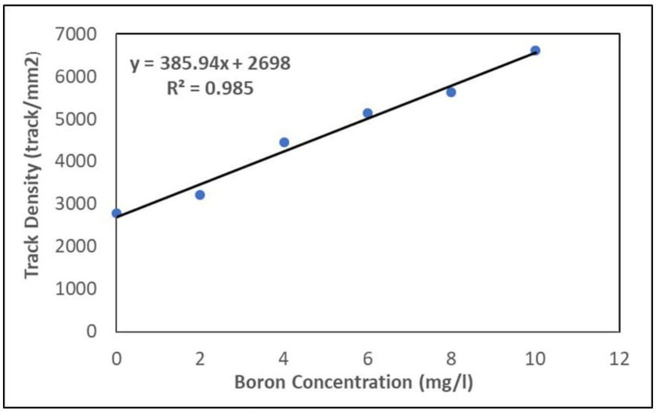

Fig. 7: Calibration curve of boron concentration in water (mg/L) vs track density(track/mm^{2})

To measure the track density on the detectors, the following mathematical equation was used***:***

$$ \boldsymbol{\rho} = \frac{\boldsymbol{N\ average}}{\boldsymbol{A}} \text{-----------------------}\boldsymbol{(4)} $$

In furtherance of the principles of CR-39 solid-state nuclear detectors (SSNTDs), a calibration curve was plotted to align our study and monitor density changes. Boron concentration was calculated using a regression equation that relates the track densities observed on sample detectors with those on reference samples. This equation is represented ، slope factor confirmed after a linear calibration check (R^2 = 0.985). The results are interpreted in units of mg/L, as shown in Figure (7), ensuring a comprehensive and accurate analysis of the boron concentration.

III. Results and Discussion

Table 1: Boron concentration and trace density Track/mm^2 in Al-Shatrah river water by using CR-39.

Sample ID	*Location*	*Track Density Track/mm^2*	*Boron Concentration (mg/L)*	
R_{Sh1}	***Al-Shatrah***	***8062.13***	***1.96***	
R_{Sh2}	***Al-Shatrah***	***7618.34***	***1.85***	
R_{Sh3}	***Al-Shatrah***	***8025.15***	***1.95***	
R_{Sh4}	***Al-Shatrah***	***8210.06***	***1.99***	
R_{Sh5}	***Al-Shatrah***	***8986.69***	***2.18***	
R_{Sh6}	***Al-Shatrah***	***9652.37***	***2.34***	
R_{Sh7}	***Al-Shatrah***	***9393.49***	***2.28***	
R_{Sh8}	***Al-Shatrah***	***8727.81***	***2.12***	
Minimum			***7618.34***	***1.85***
Maximum			***9652.37***	***2.34***
Average			***8584.55***	***2.08***

Table (1) shows the results of eight river water samples collected from different locations in Al-Shatrah station, a city located north of Thi Qar Governorate. Using the CR-39 nuclear detector, the boron content in these sites ranged between (2.34 mg/L - 1.85 mg/L). Boron concentrations in the analyzed samples ranged from 1.85 mg/L to 2.08 mg/L on average. As shown in Figure (8), it was found that the highest concentration of boron in the river water near the Al-Hijam area reached 2.34 mg/L, and the lowest concentration was 1.85 mg/L in the river water sample near Al-Hawi and Al-Abba's area.

The discrepancy in these numbers can be attributed to those waterways that are exposed to pollutants resulting from daily human waste or industrial waste.

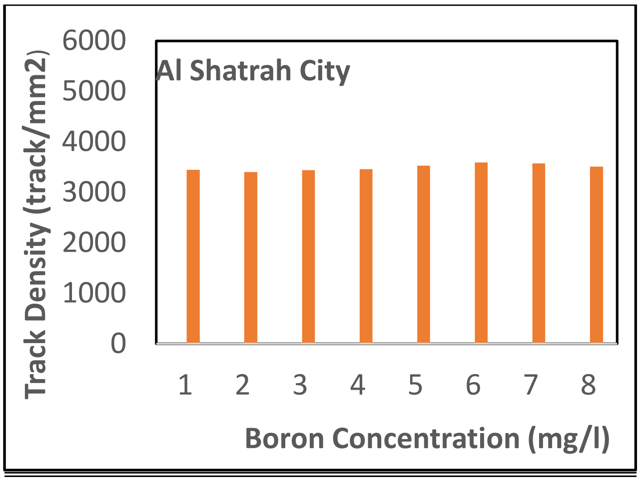

Fig.8: Boron concentration (mg/L) in water samples in Al Al-Shatrah City.

Table 2: Boron concentration and trace density track/mm^2 in The Garraf River water using CR.39

Sample ID	*Location*	*Track Density Track/mm^2*	*Boron Concentration (mg/L)*
RG1	***Garraf1***	***3293***	***2.10***
RG2	***Garraf2***	***3500***	***2.08***
RG3	***Garraf3***	***3584***	***2.32***
RG4	***Garraf4***	***3466***	***1.99***
RG5	***Garraf5***	***3581***	***2.29***
RG6	***Garraf6***	***3604***	***2.35***
RG7	***Garraf7***	***3759***	***2.75***
RG8	***Garraf8***	***3446***	***1.94***
Minimum		***3293***	***1.94***
Maximum		***3759***	***2.75***
Average		***3529***	***2.08***

Table (2) shows the results of eight river water samples taken from different locations in the Al-Gharraf region, north of Dhi Qar. Boron values in the samples ranged between 2.75 mg/L and 1.94 mg/L, with an average of 2.08 mg/L. The highest concentration of boron was found in river water, reaching 2.75 mg/L. As shown in Figure (9), the samples were collected near Al-Hurriya neighborhood. The lowest amount was 1.94 mg/L in a water sample taken near the Al-Hamza area.

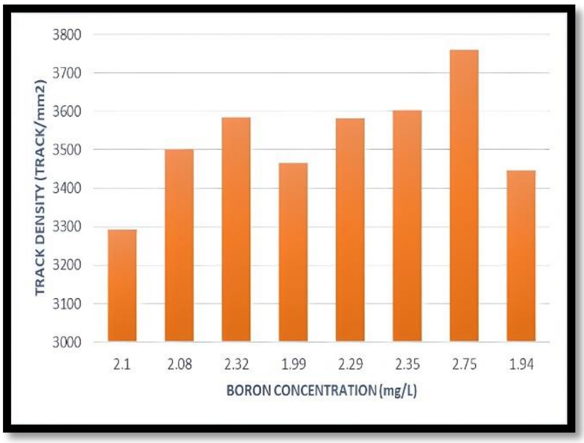

Fig.9: Boron concentration (mg/L) in water samples in the Graff using the CR39 nuclear detection device

Table (3) Boron concentration and trace density of well samples using CR-39 detectors

Sample ID	*Location*	*Track density Track/mm²*	*Boron Concentration (mg/L)*
W1	***Al-Sahlan 1***	***3415***	***1.86***
W2	***Al-Sahlan 2***	***3512***	***2.11***
W3	***Al -Sahlan 3***	***3670***	***2.52***
W4	***Al-Abu Saad 1***	***3658***	***2.49***
W5	***Al-Khinjar***	***3500***	***2.08***
W6	Al-Saeed *1*	***3662***	***2.50***
W7	***Al-Saeed2***	***3485***	***2.04***
W8	Al-Bani Zayd	***3435***	***1.91***
W9	***Al Abu Saad 2***	***3705***	***2.61***
W10	***Al Abu Saad 3***	***3516***	***2.12***
W11	***Al Abu Saad 4***	***4098***	***3.63***
W12	***Al Abu Saad 5***	***4060***	***3.53***
W13	***Al-Abu Saad 6***	***3736***	***2.69***
W14	***Al-Abu Saad 7***	***3527***	***2.15***
W15	Al-Abu Saad 8	***3801***	***2.86***
Minimum		***3415***	***1.86***
Maximum		***4098***	***3.63***
Average		***3652***	***2.47***

Table (3) shows the values of boron concentration in well water in the areas of Al-Sahlan, Al-Bu Saad, Al-Khanjar, Al-Said, and Bani Zaid in the north of Thi-Qar Governorate. Fifteen sites were randomly selected to collect well water samples. Figure (10) shows the results of these fifteen samples graded on fifteen sites, numbered W_1 to W_{15}. The Albu Saeed 4 well contains a high percentage of boron at 3.63 mg/L, while the minimum for the wells is 1.86 mg/L (Al-Sahlan 1). The results indicated that although there was a variation in boron concentrations in the wells in the areas mentioned above in Table (3), these results were close in the Al-Sahlan 2, Al-Sahlan 3, Al-Abu Saad 1, Al-Khinjar, Al-Saeed 1, and Al-Saeed 2 areas.

Al-Abu Saad 2, Al-Abu Saad 3, Al-Abu Saad 6, Al-Abu Saad 7, and Al-Abu Saad 8. Table (3) shows the values of boron concentration in well water in the areas of Al-Sahlan, Al-Busaid, Al-Khanjar, Al-Saeed and Bani Zaid in the north of Thi-Qar

Governorate. Fifteen sites were randomly selected to collect well water samples. Figure (10) shows the results of these fifteen samples classified into fifteen sites numbered from W1 to W15. Al-Busaid 4 well contains a high percentage of boron at 3.63 mg/L, while the minimum for wells is 1.86 mg/L (Al-Sahlan 1). The results indicated that although there was a variation in boron concentrations in the wells in the areas mentioned above in Table (3), these results were close in the areas of Al-Sahlan 2, Al-Sahlan 3, Al-Busaid 1, Al-Khanjar, Al-Saeed 1, Al-Saeed 2, Al-Busaid 2, Al-Busaid 3, Al-Busaid 6, Al-Busaid 7 and Al-Busaid 8. This is because the collection of these samples was during the summer, in addition to the active geothermal energy, where the concentration of boron may reach a very high level as a result of the dissolution of organic ionic compounds containing boron, and as a result of the different environmental conditions, boron compounds are also emitted and accumulate in thermal waters and enter the groundwater, thus increasing the concentration of boron [20].

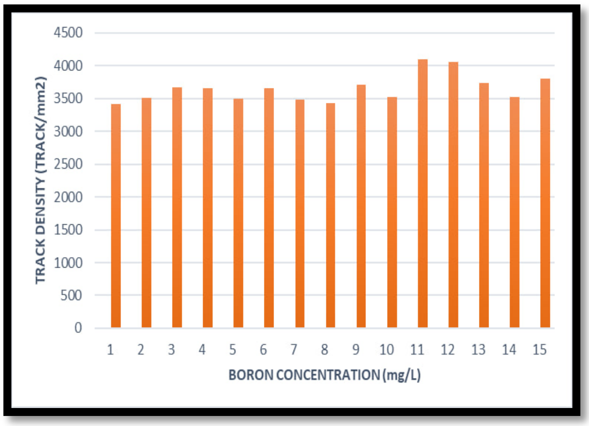

Fig.10: Boron concentration in well water samples in different locations in Thi-Qar Governorate

A study conducted in different areas to calculate the concentration of boron in river and well water in the north of the governorate showed that well water recorded the highest total concentration rate of 2.47 mg/L, while the average total concentration of boron in river water was lower, reaching 2.1 mg/L, in addition to the high temperatures and the reasons mentioned above, as well as the increase in the cultivated area and the use of some fertilizers by farmers in large quantities, as boron fertilizers are commonly used to correct its deficiency in crops, the most commonly used fertilizers are soluble sodium borate (such as borax), as the concentration of boron depends on the properties of the fertilizers and the properties of the soil [21]. These fertilizers attract the boron element to form salts and thus produce ionic compounds containing the boron element. The increasing rise in temperatures leads to the dissolution of these salts and the concentration of the boron element in groundwater and wells.

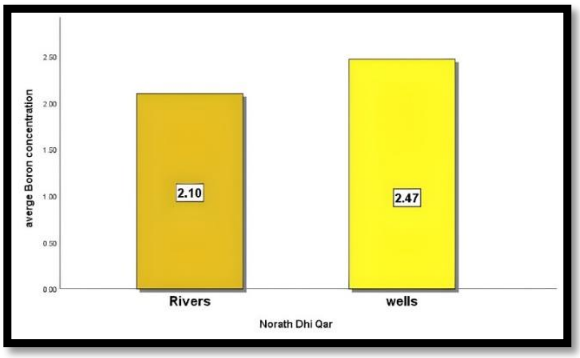

Fig.11: The variation between the average concentration of boron in river water and wells in the northern regions

IV. CONCLUSIONS

This study provides a comprehensive analysis of boron concentrations in Thi-Qar Governorate. The findings varied in terms of the amount of boron content, suggesting that there is variation among the governorate's areas. When comparing river water to well water, the quantities of boron are lower in the former. Based on the findings, it is imperative that all waterways in Thi-Qar and other governorates have their boron levels monitored on a regular basis. The study proposes establishing water treatment facilities in Thi-Qar Governorate, which includes its districts, suburbs, and the governorate headquarters. Reducing the discharge of sewage and industrial waste into the rivers of Thi-Qar Governorate.

CONFLICT OF INTEREST

Authors declare that they have no conflict of interest.

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