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Article

Evaluation of the quality of potable water in Al-Rusafa side, Baghdad, Iraq

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ABSTRACT

Safe drinking water is essential for the present and future generations' health. This study aims to assess drinking water quality in Baghdad's Al-Rusafa neighborhood. Water samples were taken from 32 neighborhoods on this side. The quality of the examined potable water samples differed depending on the water source. This investigation's pH, chlorine, EC, TDS, TSS, Cd, and Pb levels were below acceptable ranges. TDS levels in Al-Mada'in are more significant than acceptable (>600ppm) water levels. Bacteria have polluted six communities (*Shigella*, *Salmonella*, *Escherichia coli*, and *Klebsiella*). Bacterial quality of drinking water and gram-negative bacteria resistant to chlorine in Baghdad's municipal water supply. Regarding pH, the water quality, EC, TDS, TSS, Pb, and Cd of Al-Rusafa neighborhoods were within the recommended limits of WHO and the Iraqi drinking water standards.

Keywords: Safe drinking water; contaminated bacteria; Baghdad city; healthcare; pH; Temperature.

INTRODUCTION

Water is necessary for all forms of life to survive. Globally, there are growing water shortages, and the strain on current water resources is increasing due to rising demands in various sectors, including drinking, bathing, showering, agriculture, industrial operations, etc. In general, water quality is just as essential as water supply. As a result, water quality is a critical criterion for assessing environmental changes linked to social and economic development [1]. Consumption of low-quality drinking water poses several health hazards to the population, ultimately driving up healthcare costs [2].

Drinking water polluted with heavy metals, such as Cadmium and lead, is becoming a significant health problem for the general population and providers. On the other hand, the intake of polluted drinking water is the most common source of quantifiable human exposure to heavy metals. Cardiovascular problems, neurological damage, renal injuries, and the risk of cancer and diabetes are all possible side effects. Generating reactive oxygen species, which causes oxidative damage and harmful health consequences, is implicated in heavy metal-induced toxicity. As a result, using heavy metal-contaminated water causes significant rates of sickness and mortality worldwide [3].

The incidence of bacteria in the end product is called the bacteriological quality of drinking water. Contaminated water and hygiene are associated with illnesses including cholera, diarrhea, dysentery, hepatitis A, typhoid, and polio transmission. Individuals are exposed to preventable health hazards due to insufficient or poorly managed water and sanitation facilities [2].

Because of its increased oxidizing potential, low cost, ease of operation, and efficacy in improving drinking water quality, chlorination is one of the most extensively used disinfection methods. The kind and concentration (or intensity) of the disinfectant, the type and concentration of microorganisms, and the physicochemical qualities of the source water all play a part in the implementation. The disinfection procedure should strike a balance between killing or inactivating a wide range of pathogens, the ability to retain a residual, and

the development of toxic disinfection by-products [4].
Based on these findings, the current study attempted to assess the drinking water quality in Al-Rusfa by 1) evaluating physical and chemical parameters such as pH, TDS, TSS, EC, and chlorination, and 2) Cadmium lead concentrations. 3) Contaminants caused by microorganisms.

MATERIALS AND METHODS

Region of the study

Baghdad is the capital of Iraq, divided into two sides: Al-Rusafa and Al-Karkh, located in the eastern and western Tigris Rivers, respectively. This work was performed in the Al-Rusafa side, with 32 prominent residential neighborhoods. As shown in Figure 1

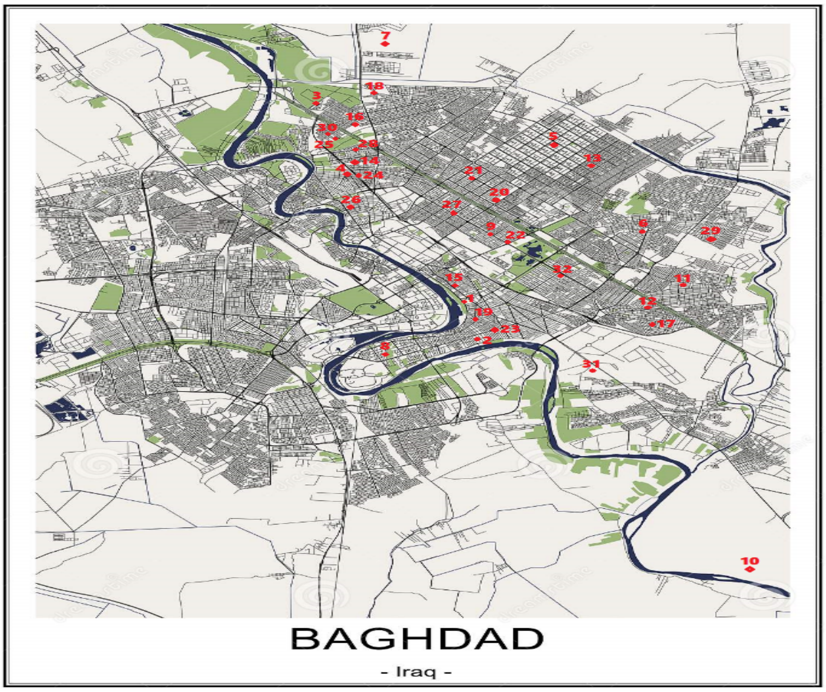

Figure 1. A map of Baghdad city showing the study areas on the Al-Rusafa side.

Water sampling

The samples of drinking water were collected from 32 neighbourhoods (Abu Nawas 1, Al-Arassat 2, Al-Basatine 3, Al-Camp 4, Al-Chwader 5, Al-Fadiliyah 6, Al-Husseiniya 7, Al-Jadiriyah 8, Al-Jwadane 9, Al-Mada'in 10, Al-Mu'almeen 11, Al-Naeria 12, Al-Obaidi 13, Al-Qahira 14, Al-Sadoon 15, Al-Shaab 16, Baghdad Aljadeeda 17, Bob Al-Sham 18, Inner Karrada 19, Jameela 20, MadinatAssadar 21, Martyrs' Gate 22, Outer Karrada 23, RaghbaKhatun 24, SabeAbkar 25, Shari Almaghrib 26, Shari Falastine 27, Slakhe 28, Swedan 29, Tunis 30, Zafaraniya 31, and Zayouna 32) in Al-Rusafa side /Baghdad province from August 2021 to December 2021 for all bacteriological, physical, chemical examinations. The samples were collected from the distribution system tap. Instead of a tap serviced by a reservoir or storage tank, a tap that provides water from a service pipe directly linked to the main pipe was chosen. All attachments were removed, and the cold-water tap was opened entirely for 2-3 minutes to clean the support line or long enough to flow out the effluent. Water was collected in sterile bottles (for bacteriological testing, 250 mL glass jars with metallic screw closures and rubbers were used, pre-sterilized in an oven at 160°C for 2 hours), sealed firmly, and delivered to the laboratories within 2-3 hours.

pH and Temperature

These parameters were measured using a Waterproof Portable pH/Temperature Meter(Hanna instrument, Romania).

Electrical conductivity and total suspended solids

These parameters were measured using Portable EC/TDS/Salinity meters (Hanna, Romania).

Total Dissolved Solids

The filtration technique used a membrane filter (LABSCO, Germany). The filtrate was dried completely in an oven at 103 - 105°C. The TDS was calculated using the following equation:

TDS mg/1= [(A - B)/ filtrated sample volume in L] x 1000 …………… (1)

Where:

A (mg) = weight of dried residue + flask.

B (mg) = weight of flask.

The results were expressed as mg/1.[5]

Free residual chlorine

It was measured in the field at the exact sample locations from tap water using a field DR-700 colorimeter (Hach) and a manual comparative chromatography using the diethyl phenyl diamine (DPD) titrimetric technique 4500-CI-F. [5]. After adding a phosphate buffer, this approach requires adding a DPD indicator solution. When the $C1_2$ oxidizes the DPD, it turns red. The results were given in parts per million (ppm).

Cadmium and Lead

Water samples were filtered to remove particulate matter. Cadmium (Cd) and lead (Pb) were estimated by the atomic absorption spectrometer (Perkin Elmer model 5000).[6]

Detection of bacteria

Water samples were cultured on Blood agar (HiMedia, India) and incubated at 37°C for 24 hrs. After that, the resultant colonies were re-cultured on MacConkey agar (Oxoid, UK) and incubated at 37°C for 24 hrs. VITEC 2 Compact (bioMérieux, France) was employed to identify bacterial isolates. The bacterial count was done using a viable count technique using phosphate-buffered saline as a diluent.[7]

Statistical analysis

Data were presented in this work as the mean of at least three replicates ± standard deviation. ANOVA one way and the least significant difference with an alpha = 0.05 were used to calculate significance using the SPSS application. A P-value < 0.05 was considered statistically significant.[8]

RESULTS

As shown in Figure 2, the pH (P < 0.05) varied among study areas, ranging from 7.0 – 7.9 ± 0.16. However, the lowest pH value (7.0) was detected in Inner Karrada, whereas the highest (7.9) was recorded in Al-Huseiniya, Al-Chwader, Slakhe, and Al-Camp.

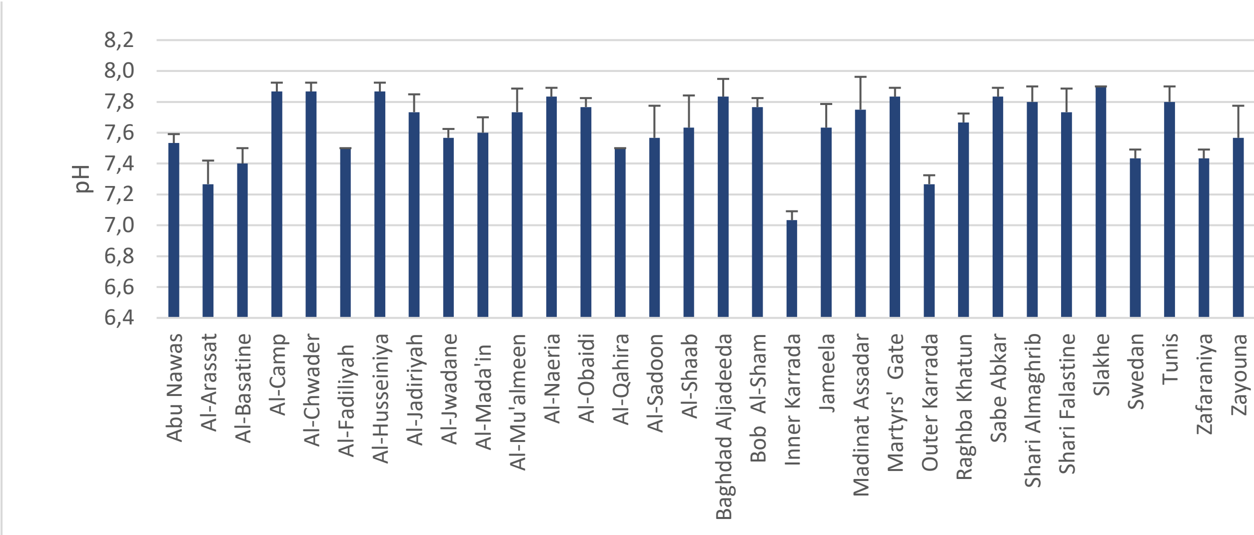

Figure 2. pH values in the tap water of Al-Rusafa side cities. P= 2.68 × 10^{-22}, LSD= 0.16.

Regarding residual chlorine (Cl), it demonstrated a significant (P < 0.05) variation among study areas as it ranged from 0.0 – 3.0 ± 0.36 ppm across all neighborhoods (Figure 3). Nevertheless, the lowest Cl value (0.0) was detected in Al-Jadiriyah, Zayouna, and Al-Shaab, whereas the highest Cl value (3.0) was recorded in Al-Mada'in, Baghdad Aljadeeda and RaghbaKhatun.

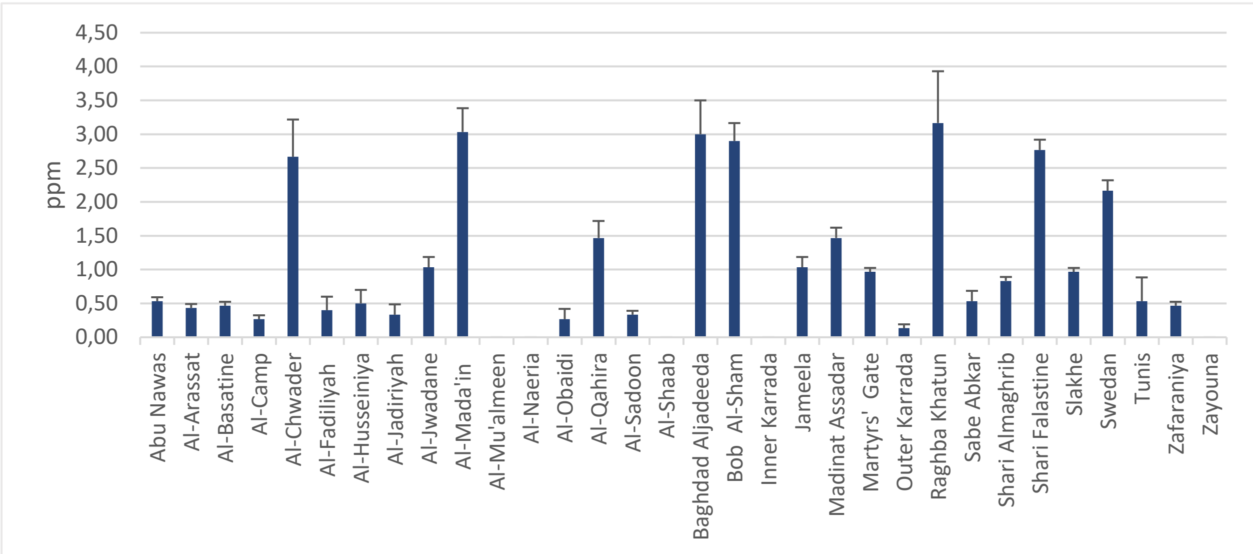

Figure 3. Residual chlorine concentration in the tap water of Al-Rusafa side cities. P= 3.46 × 10^{-48}, LSD= 0.36.

The present work found that the Electrical Conductivity (EC) ranged between 760 - 1360 ± 52.43 µS/cm (Figure 4). However, the highest level (1360 µS/cm) was recorded in Al Mada'in, whereas the lowest level (760 µS/cm) was recorded in Al-Arassat and Outer Karrada.

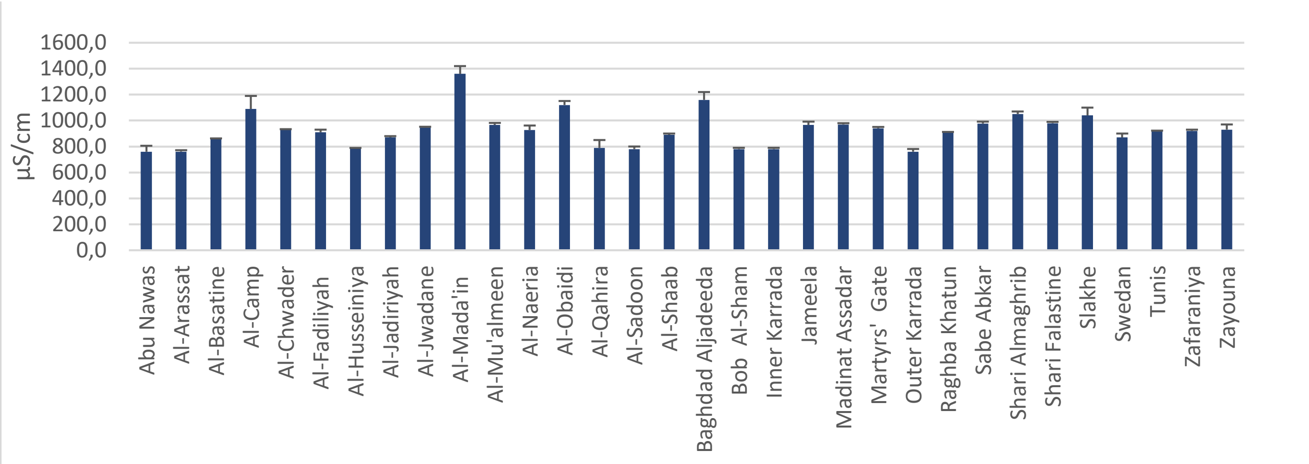

Figure 4. Electrical conductivity values in the tap water of Al-Rusafa side cities. P= 9.35 × 10^{-43}, LSD= 52.43.

The TSS values of all the drinking water samples studied are shown in Figure 5. The highest values of 12, 9, 10, and 12 mg/l were found in water samples from Al-Mada'in, Al-Arassat, and Al-Naeria, respectively. Nonetheless, the lowest values (0 mg/l) in many neighborhoods. However, it is still well below the maximum standard limit.

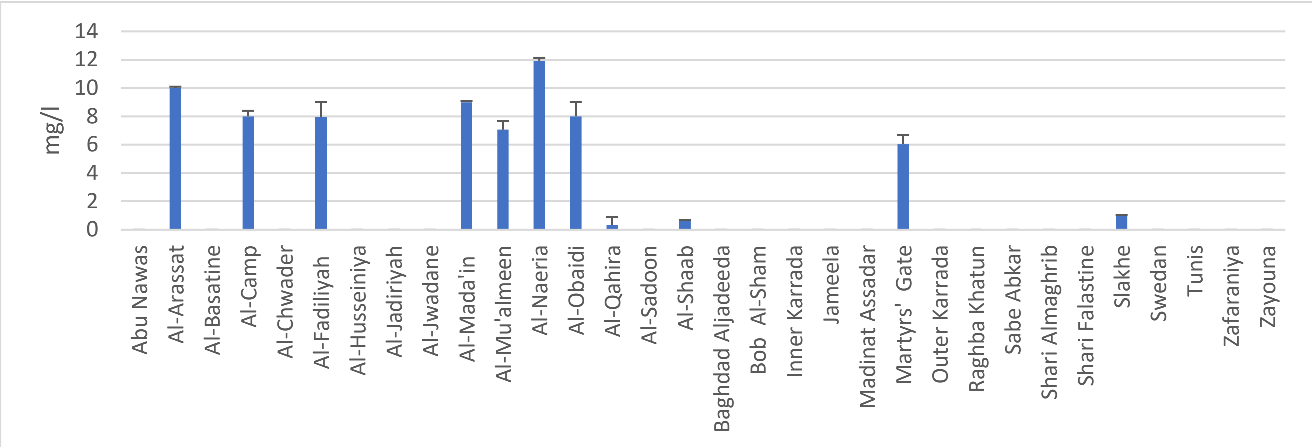

Figure 5. Total suspended solids concentrations in Al-Rusafa side cities tap water. P= 1.43 × 10^{-80}, LSD= 4.72

TDS's highest level (680 mg/1) was recorded in Al-Mada'in, whereas the lowest concentration (380 mg/1) was detected in Abu Nawas (Figure 6).

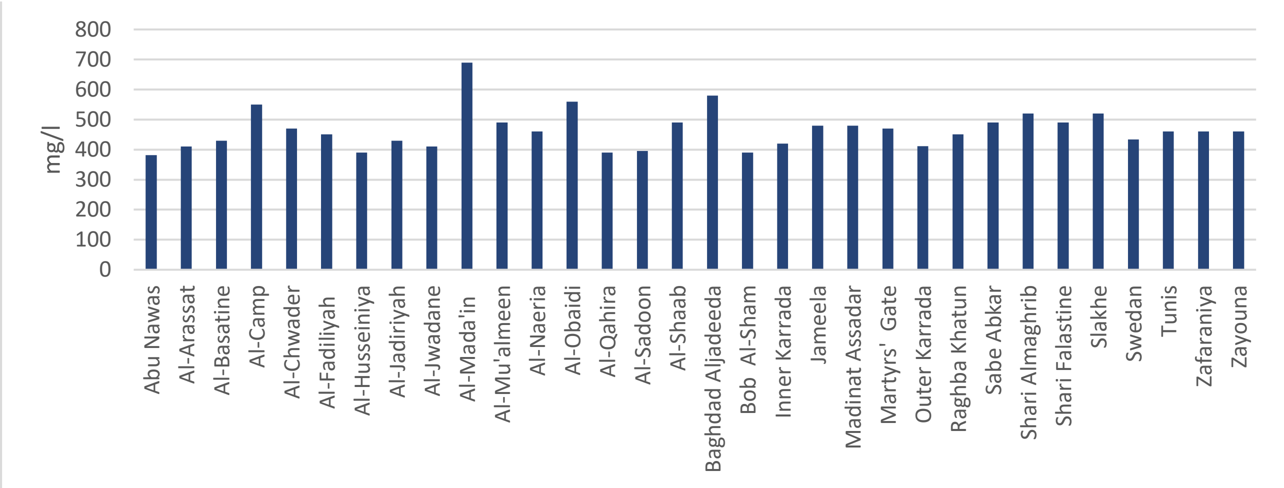

Figure 6. Total dissolved solids concentrations in Al-Rusafa side cities tap water. P= 1 × 10^{-14}, LSD= 66.14.

As shown in Figure 7, The highest concentration of Cd (0.03 ppm) was found in Zayouna, while the lowest one (0.003 ppm) was encountered in many neighborhoods. On the other hand, Pb's highest concentration (0.065,0.067,0.067, and 0.068 ppm) was in Al-Chwader, MadinatAssadar, Al-Fadiliyah, and Al-Obaidi, respectively. The lowest concentration (0.02 ppm) was detected in Slakhe (Figure 8). According to Iraqi specifications, these concentrations were accepted, and Cadmium is a naturally occurring metal in the planet's crust.

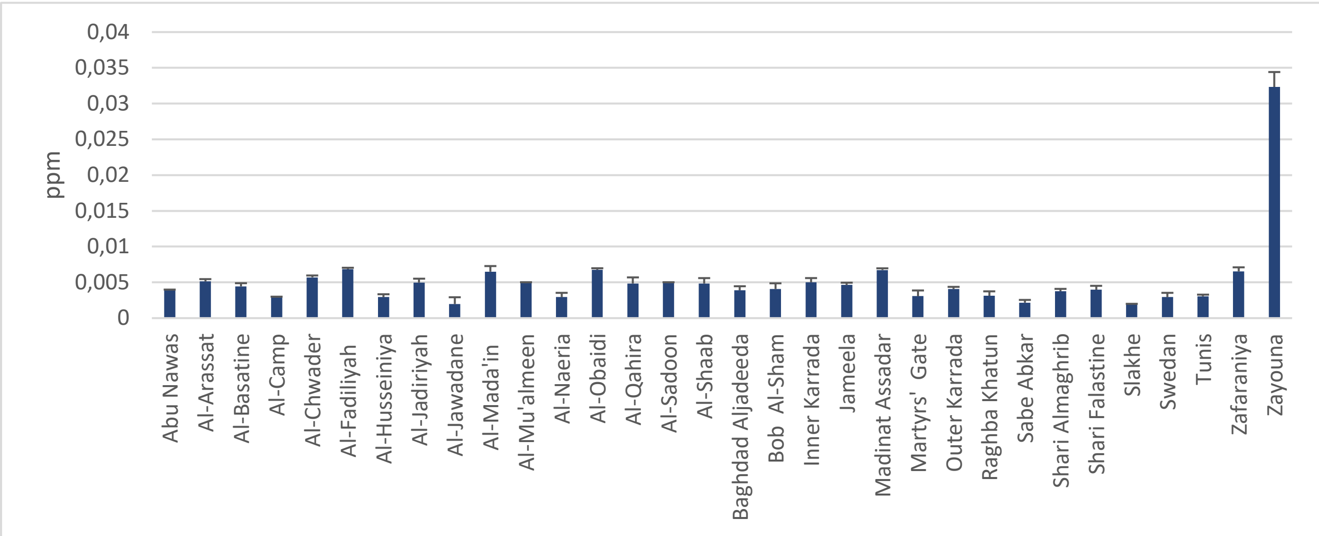

Figure 7. Cadmium concentrations in tap water of Al-Rusafa side cities. P 5.74 × 10^{-66}, LSD= 0.000948.

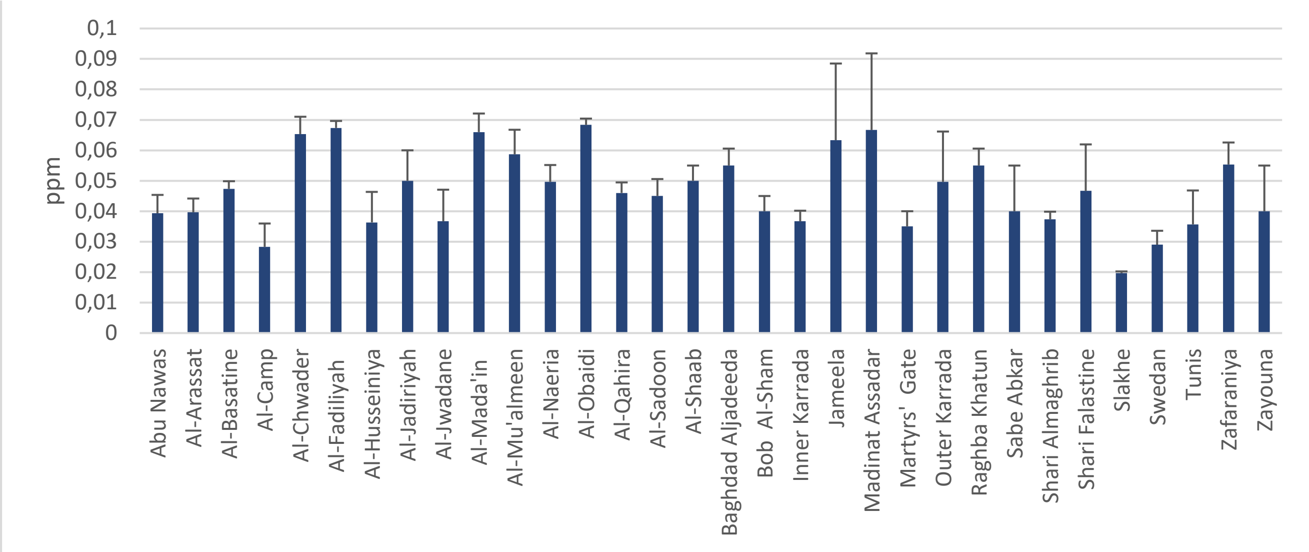

Figure 8. Lead concentrations in the tap water of Al-Rusafa side cities. P 8.67 × 10^{-11}, LSD= 0.015.

According to the microscopic examination and biochemical test, the results showed that the potable water of six neighborhoods on the Al-Rusafa side was contaminated with bacteria (*Shigella, Salmonella, E. coli*, and *Klebsiella)*

Due to old pipe projects, they may have been contaminated with sewage or inefficient precipitation and filtration processes. A low concentration of chlorine was added to the water plant. Zayouna and Al-Shaab's chlorine concentration was not detected; therefore, Salmonella's growth and Shigellawere encouraged. Similarly, the growth of *Klebsiella, E. coli,* and Salmonella was detected in Slakhe, Al-Obaidi, and Inner Karada, which had low concentrations of chlorine—furthermore, a concentration of 3.0 mgl in Mad.

DISCUSSION

The quality of drinking water, its quantity, and consumption management signify population growth. Hence, drinking water quality is vital for human and animal life.

However, according to the Iraqi Criteria and Standards of Water's chemical limitations (6.5-8.5), ICS/13.060.20 number 417/2009, second version, the lowest and highest pH values reported in this study were beyond the allowed ranges of Iraqi freshwater quality criteria.

The most raw water pH of sources lies at 6.5 to 8.5 [9]. In some areas, however, the water pH can be considerably lower due to organic acids from decaying vegetation or biological activity and dissolved carbon dioxide. Furthermore, additional alum doses precipitate calcium carbonate ($CaCO_3$) to control pipe corrosion. In addition to that, sandstorm effects increase the $CaCO_3$ concentration in Water [10]. Also, one of the essential factors influencing water pH was the rainfall during winter. Naturally, the rain is slightly acidic due to air-dissolved carbon dioxide [11]. The results of the present study are supported by other local studies [12-14].

The gradual decrease of residual chlorine concentrations from the addition point to the farthest sampling point may be due to the decomposition of chlorine when it reacts with water to hydrochloric acid. This acid is decomposed rapidly into hydrogen and hypochlorite ions [2]; due to the loss of water pressure in the pipeline, drinking water is mixed with polluted water from the environment, especially when networking pipes have fractures and cracks [15]. According to the Iraqi Criteria and Standards of Water's chemical limits, ICS/13.060.20 number 417/2009, second update, the min and max free residual chlorine values recorded in this study were within the specified range for Iraqi standards for drinking water in some neighborhoods but not in others.

The EC results may be explained by reverse osmosis treatment, removing dissolved particles, turbidity, colloidal debris, and other impurities, resulting in the lowest conductivity value. Similarly, increased mineral concentration in mineral water is predicted, resulting in higher conductivity [16].

Interestingly, most areas developed no TSS. The results varied among neighborhoods due to their filtration systems, which removed suspended particles such as silt, clay, and other inorganic particles [15]. The maximum recommended Total Suspended Solids (TSS) limit set by the Iraqi Maximum desired value is 60 mg/l [17].
According to [18], filtration systems help reduce TDS. Nonetheless, the maximum levels recorded in this research were less than 1000 mg/1, below the acceptable parameters of Iraqi drinking water standards, as defined by the Iraqi Standards and Specifications of Water's chemical limitations, ICS/13.060.20 number 417/2009, 2nd update.
Acute exposure to much greater cadmium levels can cause diarrhea, vomiting, fever, lung damage, and muscular soreness, among other things [19]. Cadmium concentrations in unpolluted natural waterways are typically below 0.003 parts per million, while the highest allowable Pb value in drinking water was 0.01 per million. Pb in drinking water is usually found in service connections and building plumbing [2]. Tetra alkyl lead in gasoline and lead arsenate as fungicides, plasters, paints, home dust, and wastewater may produce Pb pollution in metropolitan areas. The steel industry, batteries, and polymers all utilize Cd. Cadmium in the environment is also heavily influenced by wastewater and fertilizers. Cd is harmful even at low concentrations [20].
As a result, any changes in the number of microorganisms in the pipes can be attributed to flushing, chlorination, or attachment to or release from the biofilm, which may be ineffective since the biofilm protects the bacteria [21].
E. coli was the most common, followed by *Citrobacter* spp., *Shigella* spp., *Enterobacter* spp., *Providencia* spp., *Klebsiella* spp., *Salmonella* spp., *Pseudomonas* spp., *Proteus* spp., *and Edwardsiella* spp. At 0.2 mg/l for a contract duration of 30 minutes, all eight genera of a Gram-negative [21].
Total coliform was identified in those samples below the recommended amounts for free residual chlorine, according to [22-23]. The adhesion of microorganisms to surfaces dramatically increased disinfection resistance, according to [24]. Other factors that boosted disinfection resistance were biofilm age, bacterial encapsulation, and prior growth circumstances, which raised chlorine resistance by 2- to 10-fold.
Because water treatment facilities cannot eradicate all Coliforms, the effectiveness of drinking water treatment against gram-negative bacterial isolates should be checked regularly [25]. Chlorine-resistant microbiological species should be retrieved from chlorinated water distribution systems if they exist [26]. As a result, this research was conducted to evaluate drinking water's physicochemical and microbiological quality and investigate chlorine-resistant gram-negative bacteria in Baghdad's municipal drinking water supply.

CONCLUSIONS

The study concluded that the physicochemical and microbiological quality of drinking water in Baghdad is not up to the acceptable standards of Iraqi drinking water. The pH of the water was found to be outside the acceptable range, and the levels of chlorine, TDS, and Cadmium were also higher than the recommended values. The microbiological analysis revealed the presence of coliform bacteria, which can indicate contamination with fecal matter. The researchers also found that the water contained chlorine-resistant gram-negative bacteria. These bacteria can survive the chlorination process used to disinfect drinking water and pose a health risk to the population.v
The water quality in Al-Rusaf neighborhoods' pH, EC, TDS, TSS, Pb, and Cd was within the recommended limits of WHO and the Iraqi drinking water standards. However, *E. coli, Klebsiella, Salmonella, and Shigella* were detected in six neighborhoods.

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Conflicts of Interest: The author declares no conflict of interest.

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