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Evaluating The Role Of Water Quality In Diarrheal Disease Prevalence: A Case Study From Al-Kadhimiya And Al-Amiriya, Baghdad

Sarah Hameed Jawad[1], Aliaa H. Mizhir[2]
[1,2]Ecology Department, Faculty of Science, University of Kufa Najaf, Iraq

Abstract
This study examined the relationship between drinking water quality and diarrheal infections, with a particular focus on Entamoeba histolytica in Baghdad Province, Iraq. A total of 200 stool samples from diarrheal patients were microscopically examined for parasitic forms, while 36 drinking water samples were collected from Al-Kadhimiya and Al-Amiriya and analyzed for key physico-chemical parameters, including pH, electrical conductivity (EC), total dissolved solids (TDS), total hardness (T.H), calcium (Ca^{2+}), magnesium (Mg^{2+}), and chloride (Cl^-).
Findings revealed significant temporal and spatial variations in water quality, particularly elevated EC, TDS, and T.H levels by February 2025. Strong correlations were observed between T.H and Mg^{2+}, and between EC and TDS, suggesting ionic contributions to water chemistry. Epidemiological data demonstrated a statistically significant link between E. histolytica infection and diarrhea prevalence. Notably, the prevalence of E. histolytica cysts showed a strong correlation with Cl^- concentrations, indicating potential fecal contamination. Additionally, elevated TDS and Mg^{2+} levels were associated with increased diarrheal incidence, possibly due to their gastrointestinal effects.
The results highlight the importance of routine water quality monitoring and integrated public health interventions to mitigate the burden of waterborne diseases in urban environments.
Keywords: *Entamoeba histolytica, diarrhea, water quality, physico-chemical parameters, parasitic infection.*

INTRODUCTION

Diarrhea remains a significant global health concern, particularly among children, where it can quickly become life-threatening due to rapid dehydration and smaller body size (WHO, 2007; Khan et al., 2004; Peterson, 2008). Defined by the World Health Organization as the passage of three or more loose or liquid stools per day or more frequent stools than usual for an individual diarrhea is a common symptom resulting from various infectious agents, including bacteria, viruses, and protozoan parasites such as Giardia lamblia, Entamoeba histolytica, and Cryptosporidium (Ramaswamy & Jacobson, 2001).
Among these, Entamoeba histolytica is a pathogenic protozoan responsible for amebiasis, a disease of global importance that is especially prevalent in low-income countries. It is estimated that E. histolytica causes approximately 450 million infections and up to 100,000 deaths annually, predominantly in areas where sanitation and water quality are poor (AlShaibani et al., 2023). The parasite is transmitted through the ingestion of contaminated water or food and thrives in environments where inadequate infrastructure, poor hygiene, and low health awareness prevail (Saba et al., 2020).
Waterborne transmission of E. histolytica is facilitated by polluted drinking water systems, especially in urban areas with aging infrastructure or insufficient sewage management. According to WHO guidelines, safe domestic water is essential for drinking, cooking, and personal hygiene. However, pipeline contamination, often due to damaged infrastructure or low water pressure, remains a critical challenge in many developing countries (Dib et al., 2023). Although water covers over 70% of the earth's surface, only 2.5% is freshwater, and a significant portion of the global population still lacks access to clean drinking water (Nsoh et al., 2016; Bichi & Amatobi, 2013). The consequences of this are severe waterborne diseases account for approximately 3.4 million deaths annually, including around 1.4 million among children (Abuseir, 2023). In Iraq, several studies have demonstrated the epidemiological link between contaminated water and parasitic infections. For example, a study by Shnawa (2009) involving 4,064 fecal samples in Karbala revealed E. histolytica in 13.7% of patients suffering from diarrhea, with the highest prevalence observed among adults aged 30-40 years. The parasites were also detected in tap water and food sources, underscoring the role of environmental

contamination in disease transmission, particularly in densely populated and economically disadvantaged areas.

Access to clean water is both a fundamental human need and a right. Understanding the relationship between water quality and parasitic infections is therefore essential for public health planning. This study aims to investigate the correlation between drinking water quality and the incidence of diarrhea in Al-Kadhimiya district, considering environmental, social, and economic factors that contribute to disease burden.

MATERIALS AND METHODS

1. Sample Collection and Examination:

A total of 200 stool samples were collected from patients presenting with symptoms of diarrhea at Al-Kadhimiya General Hospital in Baghdad province. The collection period extended from December 2024 to April 2025. Each sample underwent macroscopic (gross) and microscopic examinations as outlined below.

2. Gross Examination

The gross characteristics of the stool samples were examined immediately after collection. The examination included assessment of consistency, presence of blood, mucus, and color. The presence of visible blood or mucus was noted, as these findings may suggest parasitic or bacterial infections (Hendrix & Robinson, 1996).

3. Microscopic Examination (Direct Smear Method)

Microscopic analysis involved the use of the direct smear technique for the detection of intestinal protozoa and helminthes as following: A small portion of each stool sample was emulsified with a drop of normal saline solution (0.9%) on a clean glass slide. Another smear was prepared using Lugol's iodine solution to enhance the visualization of protozoan cysts and trophozoites. A sterile wooden applicator stick was used for mixing. The prepared slides were then examined under a light microscope using 10× and 40× objectives for parasitic forms, including trophozoites and cysts of protozoa, as well as eggs and larvae of helminthes (Cheesbrough, 1987; McArthur, 1976).

4. Water Quality Tests

Drinking water samples (36 samples) were collected from two locations: Al-Kadhimiya and Al-Amiriya, from December 2024 to April 2025. Sampling was conducted twice monthly, with three replicates obtained at each site during each sampling event. Water quality analysis was performed according to the standardized procedures outlined in APHA (2017). The analytical methods employed for each parameter were as follows:

4.1. pH Measurement:

Before analysis, measure the pH of the sample using a digital pH meter that is properly set up with 3 different buffer solutions of pH 4.0, 7.0, and 10.0. Rinse the pH meter with fresh water between each measurement to avoid contamination from other sources. Take measurements immediately following the calibration process and write down the pH value following the reading's stabilization (±0.01 units).

4.2. Electrical Conductivity (EC):

Before each use, the conductivity was measured with a Milte conductivity meter that was properly configured with a 1413 µS/cm KCl standard solution. The samples were assessed at a temperature that was consistent at 25.0±0.5 degrees Celsius. The results were expressed as micro-Siemens/cm (µS/cm) and used to calculate the concentration of ions in the water.

4.3. Total Dissolved Solids (TDS):

The TDS were measured with a portable digital meter and the results were expressed in milligrams per liter. The TDS values are determined by weighting. Take 100 milliliters of the sample and place it through a pre-weighed filter of Whatman No. 42 filter papers, place them in a fresh, pre-dried dish that evaporates completely in an oven at 180°C for 1 hour. Cool the food down in a desiccator and then re-weigh it. Keep a written account of the total solids gained in milligrams per liter of the total dissolved solids (mg/L). To calculate the TDS value, simply add the EC value to a conversion factor of 0.64 (for low saltwater habitats) as recommended by the American Public Health Association (APHA) (2017).

4.4. Total Hardness (T.H):

The total hardness of the clay was estimated by titration with ethylenediaminetetraacetic acid (EDTA) as the titrant. Take a sample of water that has a volume of 50 ml and make it 10.0 with a buffer that contains ammonia and chloride. Indicate the presence of chrome ions by adding them to a wine-red complex that is composed of calcium and magnesium ions. Titrate with 0.01 M EDTA until the color of the solution changes from red to blue, which is the point at which the titration is complete. Calcule the concentration of dureza in milligrams per liter as $CaCO_3$. All materials and procedures employed are documented in the 2340 C method of APHA (2017).

4.5. Chloride (Cl^-) Concentration:

The total hardness of the clay was determined by titration with ethylenediaminetetraacetic acid (EDTA) as the titrant. Take a sample of water that has a volume of 50 ml and increase its concentration by 10.0 with a buffer that contains ammonia and chloride. Indicate the presence of chrome ions by adding them to a wine-red complex that is composed of calcium and magnesium ions. Titrate with 0.01 M EDTA until the color of the solution changes from red to blue, which is the exact point at which the titration is complete. Calcule the concentration of hardness in milligrams per liter as $CaCO_3$. All materials and procedures used are recorded in the 2340 C method of APHA (2017).

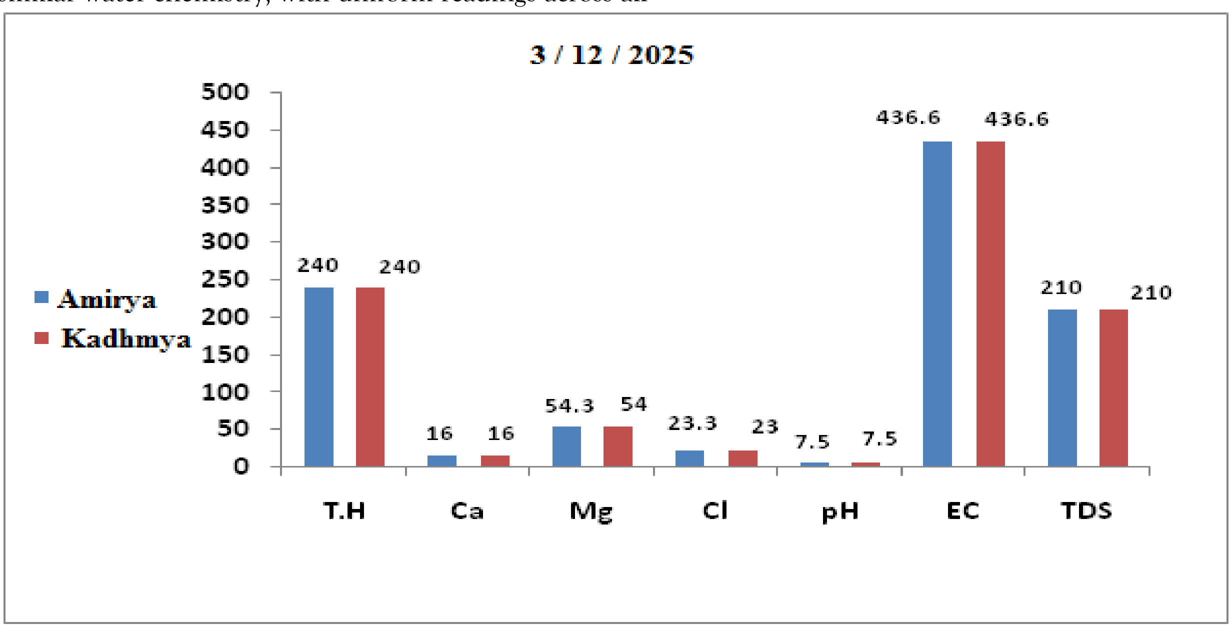
4.6. Calcium (Ca^{2+}) and Magnesium (Mg^{2+}):

The concentration of calcium was separately measured by means of EDTA titration at a pH of 12-13 with ammonium murexate as the sole indicator. The total soil hardness (sum of Ca and Mg) was determined using Eriochrome Black T at a pH of 10. The concentration of magnesium was estimated by taking the difference between the total hardness of the calcium and the hardness of the parathese. Flame atomic absorption spectroscopy (AAS) was used to authenticate the samples that were selected at the wavelengths of 422.7nm (calcium) and 285.2nm (magnesium). All procedures were conducted according to the APHA method of 3538-Ca B and 3538-Mg B.

RESULTS

1. Water Quality parameters:

Figure 1 presents a comparative analysis of the physico-chemical properties of water samples collected from two sites (Amiriya and Kadhimiya) from December 2024 to February 2025. Key water quality parameters examined include Total Hardness (T.H), Calcium (Ca), Magnesium (Mg), Chloride (Cl), pH, Electrical Conductivity (EC), and Total Dissolved Solids (TDS). On December both locations exhibited remarkably similar water chemistry, with uniform readings across all



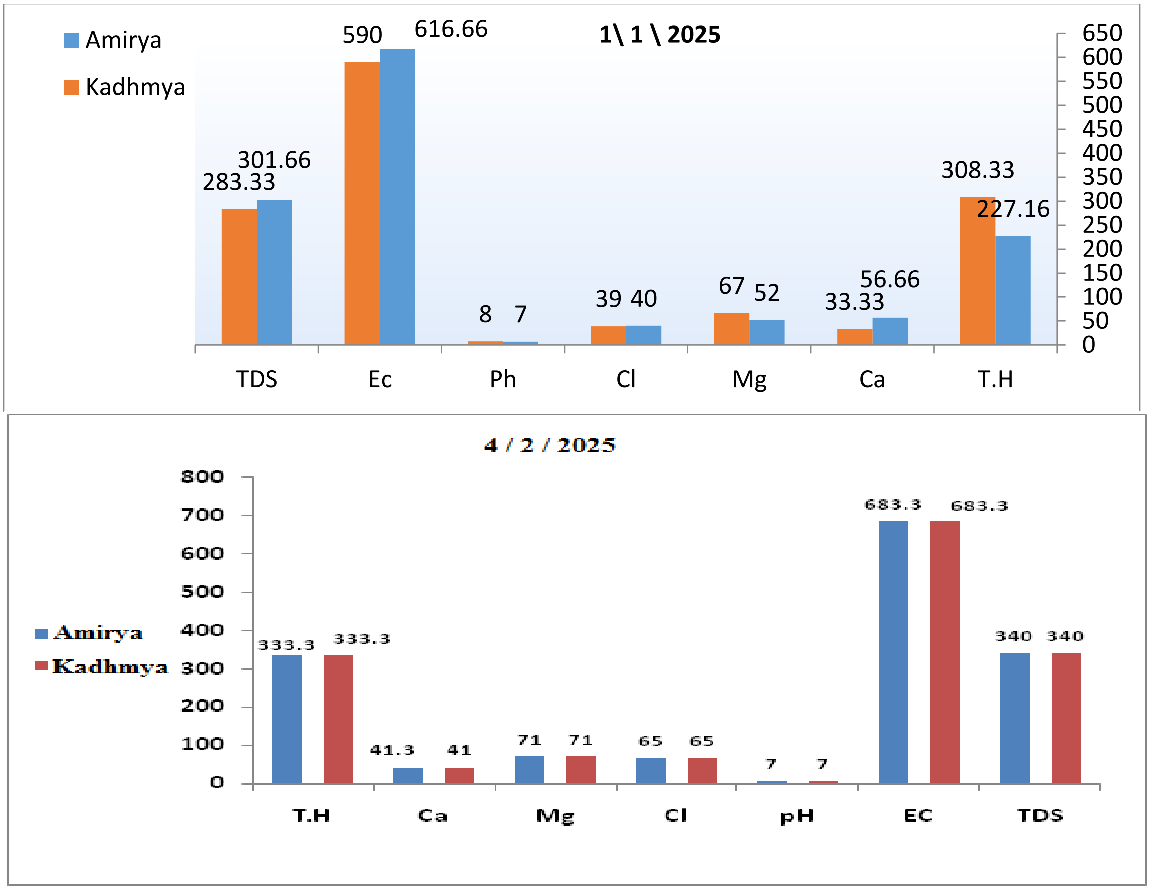


Figure 1:Temporal Comparison of Water Quality Parameters in Amiriya and Kadhimiya from December 2024 to February 2025

parameters, indicating a stable baseline. However, on January, pronounced spatial variability emerged. Notably, Amiriya showed elevated T.H and Ca levels, while Kadhimiya exhibited higher EC, Mg, and Cl concentrations. pH levels also differed. By February, both sites showed uniformly elevated values of EC, TDS, and T.H, reflecting a possible seasonal trend of increased mineral content. The data suggest a temporal shift in water quality, with implications for environmental monitoring and public health.

correlation analysis Table 1 was employed to evaluate the strength and direction of associations between these variables. Results revealed a highly significant positive correlation between T.H and Mg ($r = 0.96$, $P < 0.01$), indicating that magnesium is a major contributor to water hardness in the study area. Similarly, strong positive correlations were found between T.H and Cl ($r = 0.76$, $P < 0.01$) and between EC and TDS ($r = 0.97$, $P < 0.01$), reflecting the ionic contribution of dissolved solids to electrical conductivity. Moderate correlations were also observed between T.H and pH ($r = 0.66$, $P < 0.05$) and between Mg and Cl ($r = 0.70$, $P < 0.05$). However, other relationships, such as those between hardness and EC or TDS, were not statistically significant. These findings suggest that while certain parameters are closely linked due to common geochemical or anthropogenic sources, others may vary independently due to differences in ionic composition.

Table 1: Interrelationships Among Key Water Quality Indicators in Baghdad's Urban Areas: Statistical Insights from Amiriya and Kadhimiya.

Correlation	T.H	Ca	Mg	Cl	PH	EC	TDS
T.H	1.00						
Ca	0.54 N.S	1.00					
Mg	0.96**	0.30 N.S	1.00				
Cl	0.76**	0.56 N.S	0.70*	1.00			
PH	0.66*	0.56 N.S	0.57 N.S	0.35 N.S	1.00		
EC	-0.51 N.S	-0.38 N.S	- 0.47 N.S	-019 N.S	-0.61 N.S	1.00	
TDS	-0.64 N.S	-0.48 N.S	-0.57 N.S	-0.25 N.S	-0.77*	0.97**	1.00

N.S (No significant) , * significant correlation ($P<0.05$) , ** significant correlation ($P<0.01$)

2. Associations Between Water Quality Indicators and Diarrheal Infections in the Study Population:

During the study period, the results a total of 200 stool samples were examined from patients suffering from diarrhea who attended Al-Kadhimiya General Hospital revealed in Figure 2 that a moderate positive and statistically significant correlation ($P < 0.05$) between the prevalence of E. histolytica infection and reported cases of diarrhea. The upward trend in the data points indicates that as the number of E. histolytica cases increases, the incidence of diarrhea also tends to rise.

Figure 3 reveals a strong and highly significant positive correlation ($P < 0.01$) between the percentage of E. histolytica cysts and chloride ion (Cl^-) concentrations in water samples collected from two sites (Amiriya and Kadhimiya) from December 2024 to February 2025. The trend suggests that higher Cl^- levels are associated with increased cyst prevalence, potentially indicating fecal contamination or sewage intrusion, as chloride is often used as an indirect marker for such pollution.

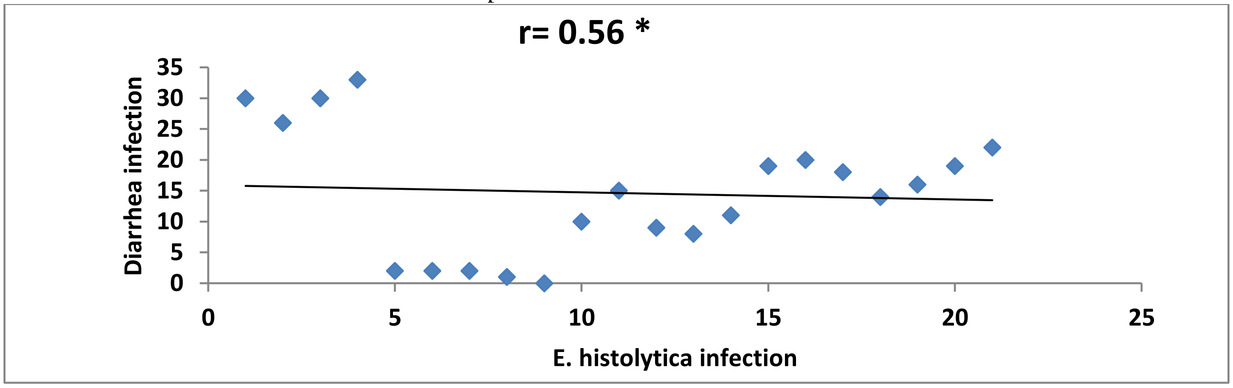


Figure 2: Correlation Between E. histolytica Infection Rate and Diarrhea Incidence

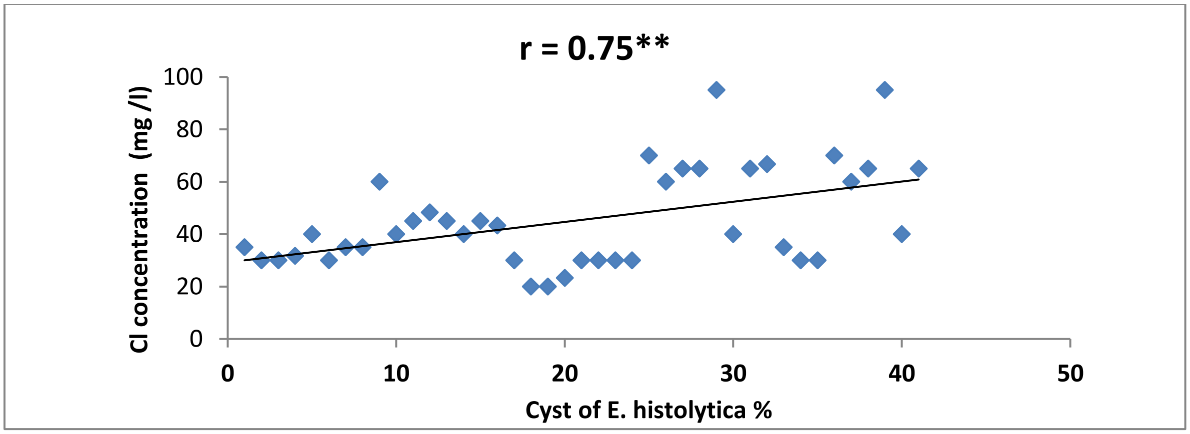


Figure 3: Relationship Between E. histolytica Cyst Prevalence and Chloride (Cl^-) Concentration in Water Samples

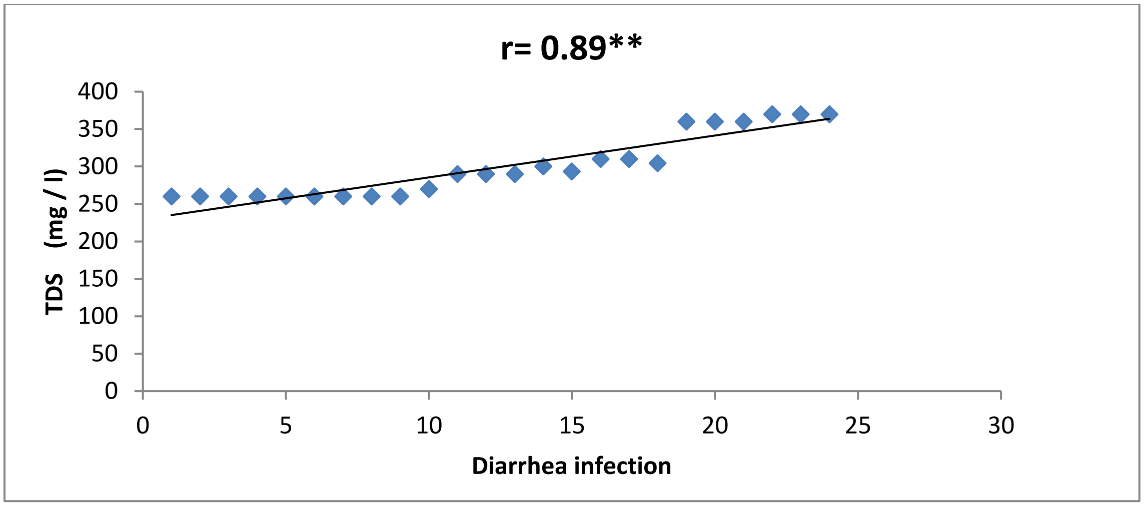


Figure 4: Association Between Diarrhea Incidence and Total Dissolved Solids (TDS) in Drinking Water

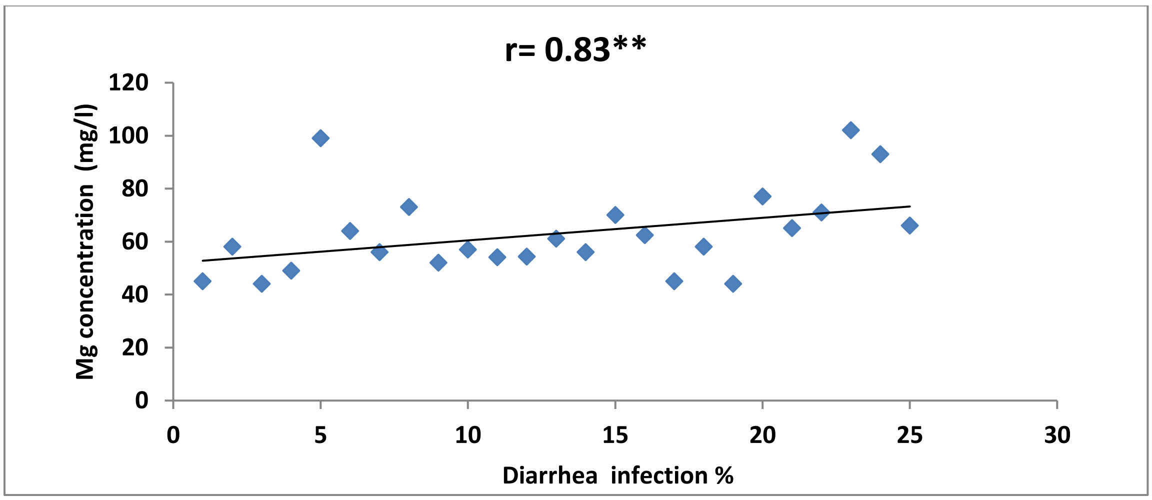


Figure 5: Correlation Between Diarrhea Infection Rate and Magnesium (Mg^{2+}) Concentration in Water

Figure 4 demonstrates a very strong and statistically significant positive correlation ($P < 0.01$) between the incidence of diarrhea and the concentration of total dissolved solids (TDS) in drinking water.

Figure 5 illustrates a strong, highly significant positive correlation ($P < 0.01$) between diarrhea incidence and magnesium (Mg^{2+}) concentrations in water. Elevated magnesium levels, particularly in combination with other minerals, can cause laxative effects, especially in sensitive individuals or populations unaccustomed to hard water.

The collectively results illustrate how variations in water quality both microbiological (e.g., E. histolytica) and chemical (e.g., Cl^-, TDS, Mg^{2+}) are closely associated with public health outcomes, particularly diarrhea.

DISCUSSION

The analysis presented in Figure 1 offers important insights into the temporal and spatial dynamics of water quality in urban environments, specifically within the Amiriya and Kadhimiya districts of Baghdad, Iraq, over a three-month monitoring period from December 2024 to February 2025. The physico-chemical parameters assessed namely Total Hardness (T.H), Calcium (Ca), Magnesium (Mg), Chloride (Cl), pH, Electrical Conductivity (EC), and Total Dissolved Solids (TDS) are widely recognized as fundamental indicators of water quality, both in international standards such as those established by the World Health Organization (WHO, 2017) and local regulatory benchmarks set by the Iraqi Ministry of Health and Environment (MOHE, 2020).

In December, the recorded values across both sampling sites were notably uniform, suggesting a stable hydrological and chemical baseline. This observation is consistent with previous seasonal studies conducted in Iraq, where winter conditions typically correspond to less variable water chemistry due to reduced evaporation rates and minimal surface runoff (Al-Maliki et al., 2022). However, the emergence of marked spatial differences in January characterized by higher T.H and Ca levels in Amiriya and elevated EC, Mg, and Cl in Kadhimiya highlights the influence of localized factors, such as anthropogenic discharges, variations in groundwater-surface water interactions, and infrastructure-related disparities in water distribution systems (Al-Khafaji & Al-Mayah, 2018).

The fluctuation in pH values between the two locations further underscores potential site-specific influences, possibly linked to industrial effluents, domestic wastewater inputs, or the buffering capacity of the surrounding soil and aquifer matrix (WHO, 2017). By February, the recorded increase in EC, TDS, and T.H in both sites may reflect a broader seasonal pattern of solute concentration due to lower dilution effects, increased evapotranspiration, or cumulative contamination from urban runoff. This trend has been reported in prior research examining the Tigris River and its tributaries, where dry-season dynamics often lead to elevated mineralization in urban water sources (Hussein et al., 2020).

The data suggest that while short-term water quality may appear stable, there is a detectable temporal shift that could have long-term implications for environmental health and public safety. Elevated EC and TDS, in particular, are indicative of increased ionic loads that may affect both drinking water palatability and its suitability for irrigation and industrial use (EPA, 2021). Moreover, the variability in hardness components (Ca and Mg) is critical for understanding scaling tendencies in municipal water systems and their potential impacts on household appliances and public infrastructure (Al-Khalidy et al., 2019).

In conclusion, this dataset reinforces the necessity for routine and spatially resolved monitoring of urban water sources in Iraq, especially in densely populated districts such as Baghdad. The observed patterns align with broader regional findings and support the development of adaptive water management strategies aimed at mitigating contamination risks and ensuring compliance with national and international water quality standards.

The correlation analysis presented in Table 1 provides a statistically grounded understanding of the interrelationships among key physico-chemical parameters influencing water quality in the urban areas of Amiriya and Kadhimiya.

A particularly noteworthy finding is the strong and highly significant positive correlation between T.H and Mg ($r = 0.96$, $P < 0.01$), which strongly implies that magnesium ions are the principal contributors to water hardness in the sampled areas. This result aligns with both international and regional studies that identify magnesium, alongside calcium, as a core component of water hardness (WHO, 2017; Al-Mousawi & Al-Rawi, 2020). In several areas of central and southern Iraq, including Baghdad, magnesium-rich groundwater and anthropogenic inputs have been reported to influence hardness levels (Al-Khateeb et al., 2019).

Another important association was found between T.H and Cl ($r = 0.76$, $P < 0.01$), suggesting that chloride typically associated with salinity and urban runoff may share common sources or pathways with hardness ions. This is particularly relevant in urban environments where industrial discharges, wastewater infiltration, or the use of deicing salts contribute to elevated chloride levels.

The strongest observed correlation was between EC and TDS ($r = 0.97$, $P < 0.01$), reaffirming the well-established relationship between dissolved ionic species and water conductivity. Since EC is a function of the concentration of ions in solution, and TDS reflects the total mass of dissolved solids, the nearly perfect correlation is consistent with findings in both global and Iraqi studies (EPA, 2021; Al-Mayah & Al-Saadi, 2018). Moderate but statistically significant correlations were also observed between T.H and pH ($r = 0.66$, $P < 0.05$) and between Mg and Cl ($r = 0.70$, $P < 0.05$). The correlation between hardness and pH may indicate the buffering role of hardness components in neutralizing acids in the water. Similarly, the Mg-Cl relationship might reflect geochemical similarities or concurrent pollution sources.

On the other hand, the absence of statistically significant correlations between hardness and parameters such as EC or TDS suggests that not all ionic species contributing to conductivity or total solids are involved in hardness. This distinction is important, as EC and TDS may include a variety of ions (e.g., sodium, potassium, bicarbonates, sulfates) that do not directly contribute to water hardness (WHO, 2017; Al-Zamili et al., 2022). the association between the prevalence of E. histolytica infection and reported cases of diarrhea supports the well-established role of E. histolytica as a causative agent of amoebic dysentery and intestinal inflammation. The data reinforce epidemiological findings from both global and regional studies, which identify this protozoan parasite as a key contributor to diarrheal disease burden, especially in areas with compromised water sanitation (WHO, 2017; Al-Kubaisi et al., 2020).

A strong and highly significant positive correlation ($P < 0.01$) between the percentage of E. histolytica cysts and chloride ion (Cl^-) concentrations in water samples collected from two sites (Amiriya and Kadhimiya) from December 2024 to February 2025. The trend suggests that higher Cl^- levels are associated with increased cyst prevalence, potentially indicating fecal contamination or sewage intrusion, as chloride is often used as an indirect marker for such pollution. Similar findings have been documented in Iraqi surface waters, where elevated chloride levels coincided with higher loads of microbial pathogens (Hussein et al., 2019). The data emphasize the importance of monitoring Cl^- as a water quality indicator, particularly in urban and peri-urban areas vulnerable to wastewater discharge.

TDS includes a broad range of inorganic salts and small organic molecules that can degrade water quality and influence microbial growth. The sharp upward trend indicates that increased TDS levels may directly or indirectly promote the occurrence of diarrheal diseases, possibly by altering the taste, palatability, or safety of water. These findings are consistent with international studies suggesting that elevated TDS levels may reflect broader contamination problems or contribute to gastrointestinal disturbances (EPA, 2021; Al-Azzawi & Al-Kaabi, 2018).

The result suggests a potential link between mineral composition and gastrointestinal health, a relationship that has been reported in both international drinking water guidelines and local Iraqi water studies (WHO, 2017; Al-Khalidy et al., 2019). This underscores the need to regulate not only microbial contaminants but also mineral content in public water supplies.

CONCLUSION

This study highlights a clear association between poor drinking water quality and the prevalence of diarrheal diseases, particularly infections caused by E. histolytica, in Baghdad's urban districts. The presence of E. histolytica cysts in stool samples confirms a notable parasitic contribution to diarrheal morbidity. Significant positive correlations were observed between key water quality indicators magnesium (Mg^{2+}), chloride (Cl^-), and total dissolved solids (TDS) and both infection rates and diarrhea incidence, suggesting a direct impact of waterborne contaminants on public health. Magnesium was a major contributor to water hardness and may exacerbate gastrointestinal symptoms, while elevated chloride levels serve as a reliable marker of fecal contamination and sewage intrusion. These findings underscore the urgent need for continuous water quality surveillance, improvements in infrastructure, and targeted public health interventions, including education and water safety programs, to reduce the burden of waterborne parasitic diseases in vulnerable urban communities.

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