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Assessment of Ground Water Pollution by Heavy Metals in Some Residential Areas in Kurdistan Region of Iraq

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Najmaldin Ezaldin Hassan and Siliva Jasim Mohammed

Faculty of Science, Environmental Department, University of Zakho, Kurdistan region, Iraq

Correspondence and requests for materials should be addressed to NEH (email: najmaldin.hassan@uoz.edu.krd)

Abstract

Groundwater is a precious resource, and the life of humans depends on its quality. Public health is extremely concerned about the contamination of groundwater with heavy metals that come from either anthropogenic or naturally occurring soil sources since it can have detrimental impacts on both plant and animal life. The main objective of the present study was to determine and assess the concentration of heavy metal contamination in groundwater and to understand potential sources of contamination. Heavy metals such as Zn, Cu, Pb, Mn, Fe, and Cd are examined. Atomic Absorption Spectrophotometer (AAS) testing was done on groundwater samples that were taken from 10 wells in the study area. In groundwater samples, physical factors, including Electrical Conductivity (EC), Total Dissolved Solids (TDS), and metals like Cd and Pb were found to be over the allowed levels advised by international standards. The analysis revealed that the levels of Cd and Pb in the groundwater samples exceeded those recommended by the World Health Organization, Environment Production Agency and Iraqi standards. According to the findings, the maximum concentrations of Cd, Pb, Zn, Cu, Mn, and Fe were, respectively, 0.693, 0.42, 0.402, 0.0851, 0.068, and 0.04 mg/L. The groundwater samples from the research area demonstrated levels of the heavy metals in the following order: Cd> Pb> Zn> Cu> Mn> Fe. It was concluded that two heavy metals, cadmium and lead, and the percolation of dissolved salts were to blame for the groundwater's declining quality. Due to elevated amounts of harmful metals, the community's groundwater is therefore dangerous for drinking in some areas. It was recommended that either chemical precipitation, ion exchange, or reverse osmosis be used on a regular basis to treat the heavy metal concentration in groundwater sources.

Keywords: Atomic Absorption Spectrophotometer (AAS); Concentration; Contamination; Groundwater; Heavy Metals; Kurdistan Region of Iraq

Introduction

The health and quality of human life depend on access to clean water (Avtar et al., 2019). Only a small amount of the water on earth is freshwater; the majority is saline. Due to overuse and contamination, freshwater is now a limited resource (Hassan and Ali, 2016). Groundwater makes up around 30% of all clean water in the natural world, and 53% of people on the planet get their drinking water from it. Groundwater contamination is currently one of the most significant environmental issues (Belkhiri et al., 2017). All water found below the surface of the earth in an aquifer's saturated zone is considered groundwater (Ezomo et al., 2013). They are formations that have enough saturated permeable material to produce enough water for springs and wells. Boreholes and Hand Dug Wells can be used to extract groundwater at varying depths. The majority of people on the planet rely on groundwater as their primary source of drinking water (Ezomo et al., 2013).

Water pollution has become one of the most serious environmental issues in recent years in the world (Naghipour et al., 2018). Due to their high toxicity, even at low concentrations, heavy metal pollutants are particularly significant among the numerous contaminants that influence water resources (Naghipour et al., 2017).

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However, the majority of water contaminants are compounds, like salts and heavy metals, which remain dissolved or suspended in water (Hassan and Al-Barware, 2016). The World Health Organization (WHO) estimates that 80% of infections and diseases are caused by contaminated groundwater. Urbanization, livestock, rural industrial facilities, and agricultural operations can all introduce contamination into water sources. Agriculture, industry, domestic waste, landfill leaks, and pit latrines are some specific sources of aquifer contamination (Abduljabar et al., 2020). Due to growing industrial and agricultural activity, the inadequate ability for managing freshwater supplies, and other factors, the situation could get worse (Amangabara and Ejenma, 2012).

In view of the research demonstrating the toxicity of heavy metals to human and biological systems, the issue of heavy metal pollution of water has gained significant public and scientific attention (Anazawa et al., 2004). Due to their toxicity even at low quantities, heavy metals in particular are a major problem (Marcovecchio et al., 2013). Heavy metals are significant environmental pollutants, and human activities like mining, the untreated discharge of industrial effluents containing metals from industries like steel plants, battery, thermal power plants, and excessive use of heavy metal fertilizers in agriculture are the main causes of groundwater contamination (Ullah et al., 2009).

Any metallic element with a relatively high density that is dangerous or poisonous at low concentrations is referred to be a heavy metal (Duffus, 2002). The term "heavy metals" refers to a collection of metals and metalloids with an atomic density more than 4 g/cm^3. One of the most prevalent contaminants in groundwater sources is heavy metals (Guo et al., 2022; Hassan and Umer, 2022). Some of these heavy metals are necessary for an organism's growth, development, and health, whereas others are not since they are irreplaceable and the majority of them are harmful to living things. Since the majority of these heavy metals can affect human health (positively or negatively) even at extremely low quantities, monitoring of heavy metals in environmental samples is crucial (Briffa et al., 2020). Heavy metals leach into groundwater and soil solution as concentrations in the environment rise and soils' ability to retain them declines (Liu et al., 2022). The food chain, therefore, allows for the accumulation and concentration of these harmful heavy metals in living tissues (Belkhiri and Narany, 2015). Although it is necessary for living things to consume a small amount of some heavy metals, such as cobalt, copper, iron, manganese, and zinc, higher concentrations of their consumption have been linked to dangerous effects (Belkhiri and Narany, 2015).

Even at low concentrations (1.0–10.0 mg/L), heavy metals are exceedingly poisonous and cannot be broken down by bioprocessing (Abdulrahman et al., 2019). Because they have the propensity to bioaccumulate, heavy metals are hazardous. In contrast to the chemical's concentration in the environment, bioaccumulation processes imply an increase in a chemical's concentration in a biological organism with time (Van et al., 2003). When substances are ingested and stored more quickly than they are decomposed (metabolized) and expelled, a compound accumulates in living beings. Foods should not be taken over certain limits of metals in foods set by the WHO (Lema et al., 2022). The presence of trace metals in our food should therefore be of great interest and worry to us (Abdulrahman et al., 2019).

In order to assess the potability and usability of their borehole water as a domestic water supply and suggest potential methods of treating the water against the heavy metal pollution, this study was carried out to determine the levels of heavy metals contamination of ten different functional boreholes that were distributed throughout Semel district in Duhok province. We have chosen this area due to increasing number of diseases day by day.

Material and methods

Study Area

Semel is the 3rd largest district of Duhok province in Kurdistan Region of Iraq, with a population of about 295086 (within 99,536 number of refugees) and an area of 740 Km^2. Located 8.7 miles west of Dohuk center. It is located between 36°51′30″ North latitudes and 42°51′0.35″ East longitudes (Figure 1). And it is present at 430-450 m above the sea level. This area has a semi-arid climate, with a mean annual temperature and precipitation of 19.2°C and 450-500 mm/year, respectively. In common with the majority of Upper Mesopotamia, Duhok endures scorching, practically rainless summers and chilly to cold, wet winters. Most rainfall occurs during the colder months, with late winter and early spring being the wettest.

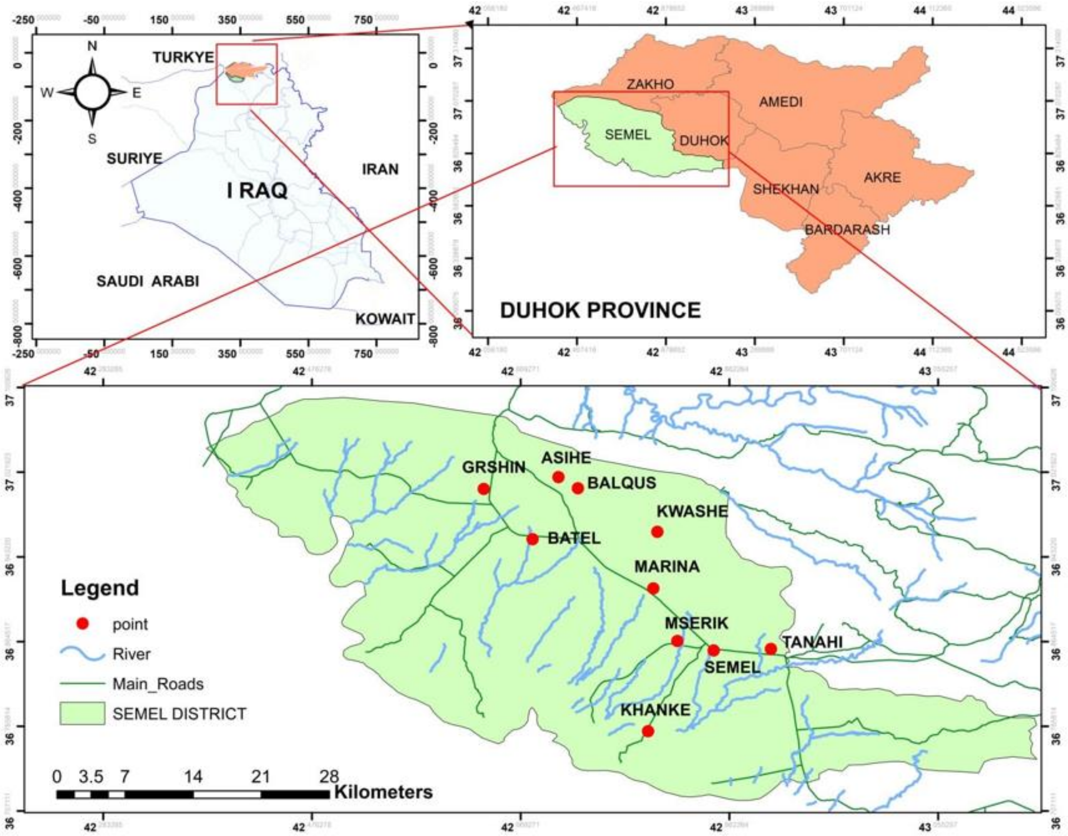

Fig. 1. Location of the study area and the sampling sites in Duhok Province of Iraq

Sample collection

Ten active wells were selected by random sampling in the study area (shown in Figure1 and the sampling location are given in Table 1). The samples were collected in October-December, 2022. Plastic bottles were used for the collection of the water samples, before the sampling proper, the sample containers were washed three times with distilled water and from each well 1.5 liter of water sample was obtained. The samples are stored in a refrigerator at 4°C until analysis is done. The parameters of EC, TDS, Turbidity and pH were measured in the Environmental Sciences laboratory at Zakho University. Heavy metals contents were analyzed in College of Agricultural Engineering Sciences Laboratory of Duhok University, by using Atomic Absorption Spectrophotometer (AAS) (Model: A-A 3600 fame- flameless HVG and MVU), these metals include; Fe, Mn, Cu, Cd, Pb and Zn.

Statistical analysis

A Past3 software tool (Paleontological Statistics), version 3.17, was used to analyses the recorded data. Furthermore, we obtained the summary data from the Past3 software. The Shapiro-Wilk normality test supported by residual plots demonstrated that all data were parametric.

Result and Discussion

According to the results of ten places' physico-chemical and heavy metals analysis, the pH of the water ranged from 6.9 to 7.5, falling within the standard required limits (6.5-8.5) recommended by WHO (2011) and Iraqi standard of drinking water (WHO, 2011 and IQS, 2009). The pH values (Table 2) indicate slightly (weakly) acidic water, with location 3 (Batel) having the lowest value of 6.6, which is attributed to the discharge of acidic materials into the groundwater through agricultural and domestic activities, and location 6 (Kwashe) having the highest pH value of 7.5 (Figure 2), which is attributed to the disposal of municipal waste into the groundwater of the study area (Hassana and Umerb, 2022).

The analysis revealed that Table 2 and Figure 2 Turbidity values were within the range of 0.27 to 3.25 NTU. The highest reading (3.25NTU) were made at station 6 (Kwashe), and the lowest reading (0.27NTU) were made at station 1 (Asihe). The presence of landfills and industrial regions is associated with the highest turbidity concentration. The investigation revealed that the turbidity of the water did not exceed WHO (2011) or Iraqi standards for drinking water (WHO, 2011 and IQS, 2009).

Table 1: The places names and coordinates, from which groundwater samples were taken.

No.	Name	Location	
		Latitude	Longitude
1	Asihe	N 37° 1' 2.2384"	E 42° 42' 15.3224"
2	Balqus	N 37° 0' 24.8586"	E 42° 43' 19.921"
3	Batel	N 36° 57' 34.6727"	E 42° 40' 49.1884"
4	Grshin	N 37° 0' 22.6995"	E 42° 38' 6.6726"
5	Khanke	N 36° 46' 52.472"	E 42° 47' 13.5894"
6	Kwashe	N 36° 57' 59.3618"	E 42° 47' 44.6757"
7	Marina	N 36° 54' 50.1869"	E 42° 47' 30.9367"
8	Mserik	N 36° 51' 54.2311"	E 42° 48' 50.9926"
9	Semel	N 36° 51' 22.5866"	E 42° 50' 52.1415"
10	Tanahi	N 36° 51' 27.5313"	E 42° 54' 2.3472"

Figure 3 depicts the Electrical Conductivity (EC) values at all locations over the course of the investigation, which ranged from (496-1158µs/cm). The maximum value (1158µs/cm) was recorded at station 5 (Khanke), and the lowest value (496µs/cm) was recorded at station 10 (Tanahi). The results of EC were suitable for use of drinking water according to Iraqi drinking water standards, however according to WHO (2011), the value is greater than permissible (WHO, 2011 and IQS, 2009) in two wells (Mserik and Khanke), as indicated in table 2 and figure 3. Because dissolved salts and other inorganic components transport electrical current, conductivity increases with salinity (Sardana et al., 2022). These results suggest a high concentration of dissolved chemical ions in these two wells because the feeding water is passing through more soluble rocks of calcite. According to the geological formation of the feeding area, conductivity is primarily naturally occurring. Figure 3 indicates that the higher value of electrical conductivity of groundwater was 1158µs/cm in Khanke and such value did not conform to the WHO (2011), but conform to the Iraqi standard (WHO, 2011 and IQS, 2009).

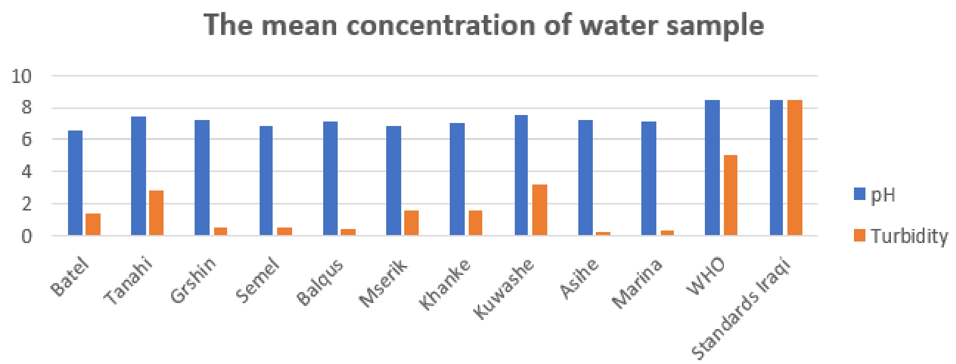

Fig.2: pH and Turbidity values of different water samples

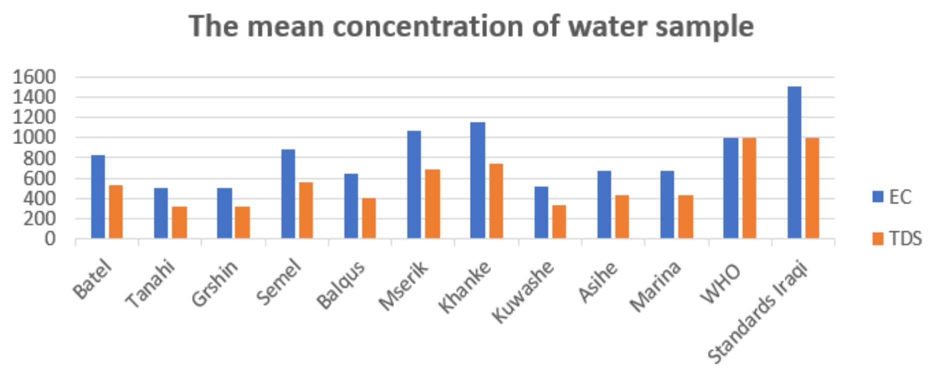

Fig. 3: EC and TDS values of different water samples

The best individual value for representing the salinity of the water is the total dissolved solids (TDS). TDS concentration values of all analyzed water samples were found to range from (318-741mg/L) for groundwater, as indicated in table 2 and figure 3. As shown in Figure 3, the highest value (741 mg/L) was at station 5 (Khanke), while the lowest value (318 mg/L) was at station 10 (Tanahi).

Total dissolved solids findings were below the upper limit and appropriate for use in drinking water (WHO, 2011 and IQS, 2009) based on WHO (2011) and Iraqi standards. The majority of wells need to be softened when used for drinking, since water with 1000 mg/L or more TDS typically produces unpleasant taste and is unpalatable. Another researcher which was found the TDS in groundwater upper the permissible limits of WHO (Pandiarajan et al., 2023).

Table 2: Statistical results of some physico-chemical parameters of water samples

Sample location	pH			Turbidity (ntu)		
	Mean	Std. Deviation	Coefficient of variation	Mean	Std. Deviation	Coefficient of variation
Batel	6.6	0.04	0.58%	1.35	0.15	11.11%
Tanahi	7.4	0.21	2.84%	2.8	0.01	3.57%
Grshin	7.2	0.07	0.98%	0.49	0.03	6.12%
Semel	6.9	0.18	2.52%	0.53	0.04	7.55%
Balqus	7.1	0.13	1.82%	0.46	0.05	10.87%
Mserik	6.9	0.22	3.17%	1.58	0.11	6.96%
Khanke	7.0	0.15	2.08%	1.6	0.2	12.50%
Kwashe	7.5	0.1	1.34%	3.25	0.13	4.00%
Asihe	7.2	0.08	1.13%	0.27	0.05	18.52%
Marina	7.1	0.2	2.81%	0.36	0.05	13.89%
WHO (WHO, 2011)	6.5-8.5			1-5		
Standards Iraqi (IQS, 2009)	6.5-8.5			1-5		
Sample location	**TDS (mg/L)**			**EC (μscm⁻)**		
	Mean	**Std. Deviation**	**Coefficient of variation**	**Mean**	**Std. Deviation**	**Coefficient of variation**
Batel	533	10	1.88%	833	12	1.44%
Tanahi	318	9	2.83%	496	16	3.23%
Grshin	325	8	2.46%	507	13	2.56%
Semel	562	12	2.14%	878	3	0.34%
Balqus	409	6	1.47%	639	11	1.72%
Mserik	680	5	0.74%	1062	21	1.98%
Khanke	741	11	1.48%	1158	8	0.69%
Kwashe	327	7	2.66%	510	15	3.66%
Asihe	429	10	2.33%	670	12	1.79%
Marina	430	5	1.16%	672	12	1.79%
WHO (WHO, 2011)	1000			1000		
Standards Iraqi (IQS, 2009)	1000			1500		

The concentration of heavy metals in the groundwater samples under examination is displayed graphically in Figures 4-5 and Tables 3a and 3b. The majority of the samples studied included metals; only a few samples lacked iron and zinc (table 3a and 3b). The mean concentrations of the heavy metals were in these ranges: Mn, 0.034–0.68 μg/L; Cd, 0.0697–0.693 μg/L; Fe, 0–0.04 μg/L; Zn, 0–0.4020 μg/L; Cu, 0.0582–0.0851 μg/L; and Pb, 0.15–0.4 μg/L. Except for Cd and Pb, whose mean concentrations are greater than the allowed range, the mean concentrations of the elements Fe, Cu, and Zn in groundwater samples are within the range (Feng et al., 2012) that the WHO (2004), Environmental protection Agency (EPA) and Iraqi Standards allow for heavy metals in drinking water (WHO, 2004 and Standard, 2009). The mean concentrations of the elements Mn, Fe, Cu, Cd, Zn, and Pb as well as their standard deviations and coefficient of variance are shown in Tables 3a and 3b. The mean concentration level of heavy metals in groundwater samples is compared with the WHO (2004), EPA and Iraqi standard maximum permissible limits in Table 3a and 3b. The concentration of heavy metals is ranked as Cd> Pb> Zn> Cu> Mn> Fe.

Table 3a: The concentration of heavy metals in water samples (mg/L)

Sample location	Mn		Fe		Pb	
	Mean	SD	Mean	SD	Mean	SD
Batel	0.05	0.0092	0	0.0	0.1575	0.0098
Tanahi	0.068	0.0019	0.013	0.0085	0.2175	0.0098
Grshin	0.064	0.002	0.04	0.0132	0.4	0.08
Semel	0.034	0.002	0.0	0.0	0.42	0.0625
Balqus	0.05	0.01	0.0022	0.0008	0.2475	0.0096
Mserik	0.057	0.0009	0.0	0.0	0.21	0.0265
Khanke	0.041	0.0095	0.0	0.0	0.2475	0.0005
Kuwashe	0.064	0.0007	0.0	0.0	0.3	0.04
Asihe	0.062	0.002	0.0	0.0	0.1875	0.0097
Marina	0.048	0.0076	0.0	0.0	0.15	0.0132
WHO (2004) (WHO, 2004)	0.1		0.3		0.01	
EPA (Feng et al., 2012)	0.1		0.3		0.01	
Iraqi Standards (Standard, 2009)	0.05		0.3		0.015	

Manganese (Mn)

In the research area's ten (10) separate sampling points, the mean concentration of manganese ranged from 0.034 mg/L in location nine (Semel) to 0.068 mg/L in location ten (Tanahi). These values are reported in table 3a and figure 4. The maximum permitted levels are 0.1 mg/L, 0.1 mg/L, and 0.05 mg/L, respectively (WHO, 2004; Feng et al., 2012; Standard, 2009). According to the WHO and EPA (WHO, 2004; Feng et al., 2012), data indicate reduced concentrations of manganese ions in all the samples that were examined, but the concentration was found to be higher than the Iraqi standards in several stations (Standard, 2009).

The high manganese levels can lead to neurological disorders, as well as stain clothing, metal pads, and precipitate in food, and it also encourages the growth of algae into reservoirs (Järup, 2003). A high Mn intake can lead to Parkinson's disease, significant respiratory conditions, and harm to the central nervous system (Hassan and Umer, 2022). One of the most abundant metals in earth's crust is manganese, which is present in the form of oxides and hydroxides. The majority of the manganese contamination in some areas of the world's water comes from suspended particles caused by burning human activities, soil erosion, volcanic and industrial emissions.

Iron (Fe)

As indicated in table 3a, the study region has ten (10) different sampling points, with the minimum and maximum mean concentrations of Iron varying from 0.0022mg/L in location two (Balqus) to 0.4mg/L in location four (Grshin). The WHO (2004), EPA, and Iraqi Standards have all determined the maximum allowable amount at 0.3 mg/L. As shown in Table 3a and Figure 4, Iron ions were not found in Asihe, Batel, Khanke, Kuwashe, Marina, Mserik and Semel (locations 1, 3, 5, 6,7, 8 and 9). The Iron ions detected in all locations were observed to be less than the maximum permissible limits in drinking water (WHO, 2004; Feng et al., 2012; Standard, 2009).

As a cofactor for many enzymes, iron serves a beneficial function in the metabolism of all living things, notably plants. Anemia and neurodegenerative disorders are two significant health problems that can result from an iron deficiency in human blood (Hassan and Umer, 2022). The liver, pancreas, and heart are damaged when the body's iron levels are too high and are kept there (Tchounwou et al., 2012).

Lead (Pb)

According to table 3a and Figure 4, the ten (10) different sampling stations in the study area's water sample had a mean lead concentration that ranged from 0.15 mg/L at location 7 (Marina) to 0.42 mg/L at location 9 (Semel). According to WHO (2004), EPA, and Iraqi standards, the upper limit is 0.01 mg/Land, 0.01 mg/L, and 0.015 mg/L, respectively. The maximum allowable limits of lead ion concentration in drinking water were discovered to be exceeded in all locations where lead ions were detected in the study area (WHO, 2004; Feng et al., 2012; Standard, 2009).

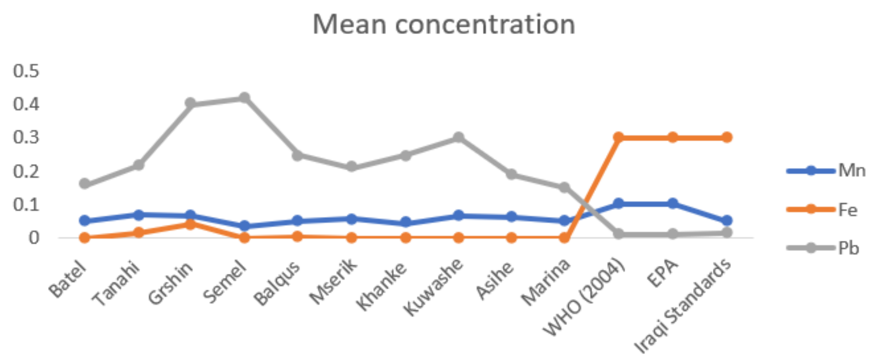

Fig. 4. Mean concentration of Mn, Fe and Pb in groundwater vs Standards

A threat to people who depend on groundwater for drinking and domestic purposes is posed by the use of littered gasoline in cars, generators, and water pumps, which can result in an abnormal concentration of lead ions. This fuel can cause cancer, interfere with vitamin D absorption, damage the nervous system, and result in brain disorders (Järup, 2003; Barbee et al., 1999). Small levels of lead can cause a variety of health issues, with children under the age of six at the greatest risk. Lead can harm kidneys, increase blood pressure, and affect hemoglobin production, among other things (Lantzy et al., 1979). Lead is ingested through breathing or gulping, and the sensory system is where lead does the most harm. Lead exposure can also result in shortness in the fingers, wrists, or lower legs, as well as premature labor in pregnant women (Coupe et al., 2013). Some metals are harmful even at relatively low concentrations and are not utilized by the majority of organisms (e.g., Pb, As) (Riaz et al., 2023).

Table 3b: The concentration of heavy metals in water samples (mg/L)

Sample location	Cd		Zn		Cu	
	Mean	SD	Mean	SD	Mean	SD
Batel	0.693	0.016	0.1982	0.0032	0.0582	0.0032
Tanahi	0.0703	0.0013	0.1062	0.0051	0.0742	0.0041
Grshin	0.0697	0.007	0.3674	0.0094	0.0712	0.0022
Semel	0.071	0.004	0.0	0.0	0.075	0.0035
Balqus	0.0734	0.0033	0.0031	0.0005	0.0781	0.0021
Mserik	0.0761	0.0011	0.0	0.0	0.081	0.002
Khanke	0.0767	0.0014	0.0	0.0	0.0851	0.0016
Kuwashe	0.0737	0.003	0.0	0.0	0.0834	0.0032
Asihe	0.0754	0.0034	0.0	0.0	0.0817	0.0027
Marina	0.0791	0.0009	0.4020	0.4	0.0851	0.004
WHO (2004) (WHO, 2004)	0.003		3		1	
EPA (Feng et al., 2012)	0.003		3		1	
Iraqi standards (Standard, 2009)	0.005		5		1.3	

Cadmium (Cd)

The ten (10) separate sampling stations of the research region yielded a water sample with a minimum and maximum mean Cadmium concentration of 0.0697 mg/L at location 4 (Grshin) and 0.693 mg/L at location 3 (Batel). According to WHO (2004), EPA, and Iraqi guidelines, the upper allowable limit is 0.003 mg/L, 0.003 mg/L, and 0.005 mg/L, respectively (table 3b). The readings at every location were found to be higher than the upper acceptable limit for drinking water established by the WHO (2004), EPA, and Iraqi standards (WHO, 2004; Feng et al., 2012; Standard, 2009).

High levels of cadmium in drinking and household water can seriously harm lungs, as well as induce vomiting, diarrhea, and excruciating stomach discomfort. There are various sources where cadmium enters groundwater. Consuming foods that have been cultivated, particularly grains and leafy vegetables, which easily absorb cadmium from the soil, is one source. The cadmium may be present naturally in the groundwater or as a pollutant from sewage sludge, fertilizers, contaminated groundwater, or mining and industrial effluents. The pH of the water may change as Cd levels rise. Groundwater can include cadmium from a range of environmental and industrial sources (Houng and Lee, 1998).

Zinc (Zn)

According to table 3b, the study area's ten (10) separate sampling points had water samples with a mean zinc concentration that ranged from 0.0031 mg/L in location 2 (Balqus) to 0.4020 mg/L in location 7 (Marina). According to WHO (2004), EPA, and Iraqi standards, the maximum allowed value is 3 mg/L, 3 mg/L, and 5 mg/L, respectively (WHO, 2004; Feng et al., 2012; Standard, 2009). None of the Zinc ions were found in Asihe, Semel, Mserik, Khanke, or Kuwashe (location 1, 5,6,8 and 9). The Zinc ions observed in all locations were detected to be less than the standards maximum permissible limits of Zinc ion concentration in drinking water (WHO, 2004; Feng et al., 2012; Standard, 2009).

For humans, other living things, including higher plants, zinc is an essential minor component. Zinc is used to treat and prevent zinc deficiency and its effects, such as slow wound healing, acute diarrhea in children, and stunted growth. The immune system is strengthened by zinc, which also treats recurring ear infections and colds and guards against lower respiratory infections. However, consuming too much zinc through food, drink, or dietary supplements might have a negative impact on health. Long-term consumption of unquestionably high zinc doses has been linked to paleness, pancreatic damage, and decreased HDL cholesterol levels (Coupe et al., 2013). Increased zinc concentration may be the hazardous factor causing colic's, fevers, diarrhea, and stomach aches (Wang et al., 1991). The largest majority of zinc sources include the discharge of domestic wastewaters, coal-burning power plants, metal fabrication processes, and climatic consequences (Coupe et al., 2013).

Copper (Cu)

The ten (10) separate sampling stations in the research region yielded water samples with a minimum mean concentration of copper of 0.0582 mg/L at location 3 (Batel) and a maximum mean concentration of 0.0851 mg/L at both location 5 and 7 (Khanke and Marina), as shown in table 3b and figure 5. These readings were found to be below the maximum allowable limits for drinking water established by the WHO in 2004, the EPA, and Iraqi standards (1.0 mg/L, 1.0 mg/L, and 1.3 mg/L, respectively). Copper has the lowest value of mean concentration of the elements in all locations of the study.

Due to industrial waste that contains copper, agricultural pesticides, and copper pipe corrosion, copper is released into drinking water (Coupe et al., 2013). Copper is a trace element that is crucial to human health. However, a high concentration of copper can have serious health effects. Some people's kidneys and livers have been discovered to be harmed by high copper levels in drinking water. Copper can be toxic to infants under one year old, because it cannot be easily excreted from their systems. Long-term exposure to copper causes nose, mouth, and eye irritation, as well as headaches, dizziness, nausea, and loose stools (Coupe et al., 2013).

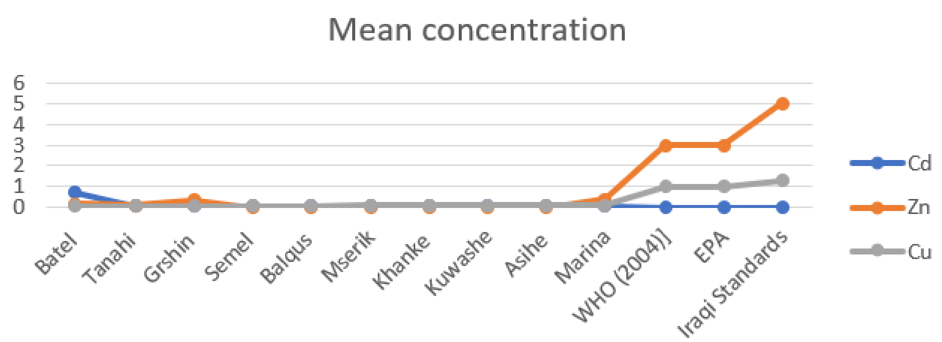

Fig. 5. Mean concentration of Cd, Zn and Cu in groundwater vs some Standards

Conclusion and Recommendation

The groundwater quality of the study area has high dissolved ions due to the dissolved rocks of some study areas. The high electrical conductivity of groundwater has a slight to moderate restriction to crop growth. Some wells required treatment to make the flavor more acceptable due to high total dissolved solids levels of more than 1000 mg/L. According to this study, the mean levels of heavy metals in groundwater sources were, in descending order: Cd > Pb > Zn > Cu > Mn > Fe. In the groundwater samples, it was discovered that Cd, Zn, Pb, Cu, Mn, and Fe concentrations were present. Nevertheless, the levels of all four of the investigated elements (Zn, Cu, Mn and Fe) were low, except Cd and Pb, which were excessive quantities to the values recommended for drinking water by the WHO (2004), EPA, and Iraqi Standards. These results imply that to reduce these dangerous levels, greater attention needs to be devoted to the water in the analyzed areas. It was determined that two heavy metals, cadmium and lead, and the percolation of dissolved salts were to blame for the groundwater's declining quality. As a result, it raises the potential of numerous ailments in the local population who use groundwater for drinking without properly treating it. Ordinary physical techniques like screening, settling, and filtering cannot separate the dissolved heavy metals; therefore, technologies like neutralization, oxidation, reduction, reverse osmosis, and ion-exchange must be used for treatment. Additional research will be needed in the future to evaluate the level of heavy metal pollution in various Duhok governorate locations using more thorough sampling in order to gain a complete picture.

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