



Trace Elements Risk Assessment in Taps Drinking Water of Ramadi City, Anbar Province, Iraq

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ABSTRACT

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The main target of this research is to assess the risk exposure into specified trace elements (TEs) in taps drinking water of Ramadi city, western Iraq. Non-carcinogenic risks (Hazardous Index) for adults and children were estimated, and carcinogenic risks (CR) were determined. Results obtained in this research indicate that the non-carcinogenic risks (NCR) analysis of (TEs) for adults and children were the most hazardous quotient (HQ) of all (TEs) values, which were less than 1, except for (As). The hazardous index (HI) of (TEs) values was more than 1, which means that there could be a potential risk to human health. Based on USEPA (2015) the safe value for cancer risk (CR) exposed by a TE is less than $1.00E-06$. Assessment of (CR) analysis of (TEs) for adults and children revealed that (CR) of (TEs) values were fell within the $E-03$ to $E-06$ range. The total average (CR) was $3.19E-03$ per capita; The total average CR was extremely high. The current concentrations of TEs in taps drinking water could cause health and environmental issues that must be addressed. Water with high (TEs) concentrations should be handled and managed before it can be distributed to consumers.

1. INTRODUCTION

Freshwater is estimated to account for less than 3% of the world's water resources, and only 1% of this is suitable for human consumption [1]. Globally, according to the United Nations World Water Development Report, in 2017 about 29% of people in different countries have not yet got safe drinking water, in the last decades, and more than 55% of people have not safely sanitation [2].

The deterioration of water quality, as well as the rise in the number of water-related diseases, were behind of necessitates the creation of a national water quality management strategic plan aimed at improving coordination and cooperation among various stakeholder groups, as well as the implementation of monitoring standards and the providing information of water quality data. To get safe drinking water, drinking water must not have harmful contaminants, such as trace elements (TEs), toxic organic substances, bacteria and viruses [3].

Trace elements with precise concentrations abound in the natural world. Human actions such as mineral extraction, refining, and manufacturing, which have increased the economy and civilization, have greatly led to more trace elements entering the air, water, and land, leads to major environmental contamination [4]. Recently, the (TEs) were considered the major origin of environmental pollution problems. Disposal of wastewater with high (TEs) contents into the environment could be harmful to ecosystems and pose impacts to people health due to refractory characteristics of bioaccumulation. Even though that, the (TEs) are essential for life operations, they were only required at the trace quantities. Critical trace elements existing with high levels in drinking water led to a negative health effect, especially, chromium, cadmium, arsenic elements that have substantial biological

toxicity and are harmful to human health [5-7]. For instance, Cadmium essentially collects in the human hepatic system and kidneys, disturbing estrogen secretion, and it is also carcinogenic [8, 9].

In addition, Chromium has the strongest biological toxicity among the trace elements (TEs) so that it can cause skin cancer for people. Copper is a much needed (TEs) for the human being body; however, it is also harmful to the kidney, liver, brain and digestive system with excessive concentrations (more than required levels) [10, 11]. Zinc is also one of the (TEs) that can cause severe problems to the digestive system, blood system and neurological system, while lack of selenium can expedite the body's aging stage, leading to diabetes, cancer, cardiovascular disease and rising other diseases [7, 12].

Therefore, globally, drinking water quality has become a great concern to the people, especially in heavily polluted rural areas. In the current study, pollution characteristics, source, and health risk assessment (HRA) of (TEs) that existed in drinking tap water (DTW) for different areas in the Ramadi city, Iraq, were investigated.

The drinking water can be mainly polluted by the (TEs) coming from domestic and industrial activities, in addition to the fatigue of the distribution network and the home network as well as inappropriate wastes disposal [13, 14].

The main source of (TEs) existed in the tap water is the corrosion of domestic piping systems. If there is contact between water with the metal coating, the corrosion usually happens over time, releasing the (TEs) into the water.

Many factors, including pipe material and pipe's internal protective lining, could highly affect the corrosion of pipe [7]. The water quality monitoring data obtained from the health facilities in this area can be also used to analyze the health concerns [15].

Table 1. Sources, risks and criteria of common TEs in water

Heavy Metal	Main sources	Health risks	Guideline(mg/L)
Lead (Pb)	Plumbing and Fittings	Neurotoxic impacts, Possibly carcinogenic	0.01
Nickel (Ni)	Naturally Occurring Plumbing and Fittings	Allergic contact dermatitis, possibly carcinogenic	0.07
Iron (Fe)	Plumbing and Fittings	Taste and appearance above guideline concentration	1-3
Chromium (Cr)	Naturally Occurring	Cr+6 (Human Carcinogen)	0.05
Arsenic (As)	Naturally Occurring	Carcinogenic	0.01
Cadmium (Cd)	Plumbing and Fitting, Industrial	Possibility Carcinogenic	0.003
Barium (Ba)	Naturally Occurring	Hypertension	1.3
Antimony	Naturally Occurring	Possibility Carcinogenic	0.02
Manganese (Mn)	Naturally Occurring	Possibility neurological impact	0.4
Mercury (Hg) (Inorganic)	Industrial	Hemorrhagic gastritis and colitis. kidney injury. carcinogenic	0.006

Water used for drinking and agricultural purposes in Iraq is poor quality, failing to meet both Iraqi National and World Health Organization Standards. The Biochemical Oxygen Demand (BOD) in water was 36.2 mg/L in 2010, more than three times the national limit of 10 mg/L, suggesting an alarming increase in water pollution. Nearly 60% of children Iraqis do not have access to clean potable water, and less than 50% of all schools in the country have basic water, putting children's health, nutrition, cognitive development, and future livelihoods at danger. People who drink dirty water will be at a higher risk of developing water-related illnesses. Many cases were caused by the drinking of water from inadequate sources [16].

The lack of information and researches about water quality and (HRA), in 2019, Iraq reported total of (140621) deaths, which is about (3.594E-03) deaths. Anbar province (study area) has (3704) deaths which are about (2.47E-03). According to the Iraqi Health ministry, data cancer disease forms the second-highest rate of deaths in Iraq which represents 9.33% in 2019. In addition, the total tumors of children were (1715) cases, which about (11.12 E-04) [17].

In China, it was found that non-carcinogenic health hazards are greater in the dry season than in the rainy season for both adults and children. During the dry and rainy seasons, the water quality indicators evaluated in the risk analysis contribute to the total non-carcinogenic risk at various levels. The average non-carcinogenic risk values of chlorinated water and terminal tap water were $F > As > NO_3-N > Cr6+$ in the summer months, and $F > NO_3-N > Cr6+ > As$ in the wet season [15]. Although numerous studies have been conducted to analyze the health risks of (TEs) in diverse sources of water, the influence of age and the content of all (TEs) in (DTW) have been overlooked. As a result, a study was done in Zahedan city, Iran to assess the (TEs) such as (As, Cr, B, Mn, Cu, Fe, Al, Se, Cd, Ni, Zn, Pb, and Hg) in the (DTW) and to determine their non-carcinogenic and carcinogenic effects based on the guidelines [3].

In Algeria, the concentration of some TEs was investigated in the surface water of Chott Merouane city to assess the possible risks of (TEs) to humans. The Hazard Quotient (HQ) and Hazard index (HI) for both adults and children through the oral route were less than one, but the HI for kids was larger than one (1.36), showing an inadequate risk of non-carcinogenic impacts on children's health. The Carcinogenic Risk (CR) was reported to be within the tolerable cancer risk range of 10⁻⁶–10⁻⁴ set by the USEPA [18]. Moreover, it was stated that both non-carcinogenic and carcinogenic risks could be substantially attributed to the oral pathway with minor adverse health risks, suggesting important conservation, mitigations, and management measures must be carried out to enhance the water quality of this water resources area [18].

In the north of China, a (HRA) in the Luan River was carried out; (CR) and (HQs) were assessed separately. The results showed that both the (CR) and HQs of Ni and Cr are larger than the acceptable guideline values [19].

Table 1 presents the popular (TEs) observed in piped drinking water, as well as their sources, WHO recommendations, and possible health hazards [20-24].

The fatality rate in Iraq has risen, as has the total number of deaths caused by malignant neoplasms (2017, 2018, and 2019) were (2738, 21766, and 22737), respectively [17].

This study goals to assess the (HRA) due to exposure to trace elements (TEs) in taps potable water pumped by the Large Ramadi drinking water treatment plant in Ramadi city, Anbar province, western of Iraq. Non-carcinogenic risk (Hazardous Index, HI) and carcinogenic risk (CR) of TEs were developed to assess the quality and risk of taps supplied water. Thirty-six locations in Ramadi were collected for a total sum of 216 taps water samples, and trace elements were then investigated.

2. MATERIALS AND METHODS

2.1 Study area

Ramadi City (RC), which is the center of Anbar province, is located in western Iraqi desert. The geographical position of RC is shown in the Figure 1. RC is a moderately urbanized city with a population of about 270,000 people, with several minor and two large industries (glass and Ceramic factories). The study area is around (6605) hectares [25, 26].

Many challenges and concerns face the RC's drinking fresh water, such as an outdated and damaged water distribution system, a current supply shortage, high consumption, and population growth. As a result, this study was conducted to assess the health risk due to contact with trace elements in potable water in the tap. This potable water is provided by the Main Ramadi Water Treatment Plant in Ramadi city.

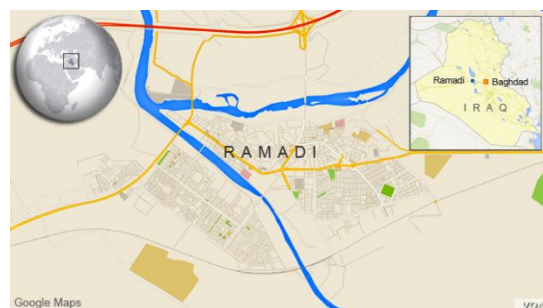


Figure 1. Geographical location of Ramadi city

2.2 Ramadi water supply

The raw water supplied for the RC mainly comes from the Euphrates River. The Large Ramadi drinking water treatment project (LRDWTP) provides drinkable water to RC using traditional treatment processes (sedimentation, filtration, and chlorination). The (LRDWTP) supplies Ramadi areas with potable water at a rate of roughly 0.25 million m³/day. The drinking water was divided into the Ramadi piping system, which made up of old iron feeder lines (diameter > 600 mm), PVC main pipes (100-150 mm diameter), and HDPE consumer connections [26].

2.3 Sampling

From December 2020 through June 2021, a sampling period was conducted. A total of 36 sites were recommended to completely cover the research region, based on the water distribution infrastructure, demographic density, and population dispersion. Measurements were taken bimonthly. 216 tests of tap water were collected during the research period of the investigation. The study area is around (6605) hectares. Geographic information systems (GIS) technology (ARC GIS.V 10.33) in research mapping and determination of water samples by using (GPS). The study area boundary and sampling station shown in (Figure 2). Sampling points were selected to covers all the Ramadi City (RC). Two samples were collected from each sampling station, then kept in a clean vessel of polyethylene, Polyethylene vessel of 1 Liter volume were used for collection samples.

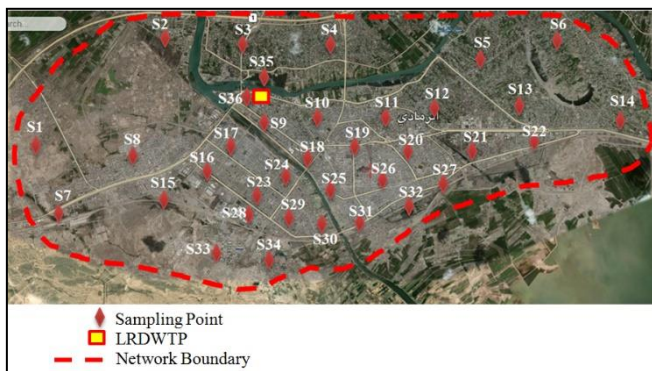


Figure 2. Study area boundary and sampling stations

Vessels cleaned with nitric acid in a ratio of 1:1 for one day, then washed with deionized water. pH values of the samples should be lowered to less than 2, therefore, high quality nitric acid poured to samples to reduce the of absorbability of trace elements in sampling vessels in accordance with [27]. After acidification, samples were then put in the cooling (incubator) at 4°C. The As, Cd, Cr, Ni, Pb, and Fe element concentrations were measured and analyzed using the Atomic Absorption Spectrophotometer instrument (AAS), (Phoinex-986), and it was calibrated by a certified standard solution. The AAS, A standard reagents was used to verify the device calibration status after every 10 examined measurements. If the standard deviation readings were greater than ten percent, the instrument must be recalibrated.

2.4 Assessment of human health risk (HHRA)

Risk assessment (RA) is the process of evaluating the

likelihood of accident occurrence or the likelihood of a harmful health impact on humans or other animals exposed to environmental risks [28].

TEs have been found as being a substantial challenge and danger to human. TEs may enter the body through a variety of routes, including cutaneous, ingestion, and inhalation, oral ingestion is the most common and major route [29].

Generally, when humans are exposed to low chemical doses, the exposure intake rate has a linear relation with human (CR). However, when a high intake results in a higher (CR), there is an exponential relation between the exposure dose rate and human (CR). The average chronic daily intake (ACDI_i) by ingestion route may be estimated using the equation below [30-33].

$$ACDI_i = \frac{C_w \times IR \times ED \times EF}{BW \times AT} \quad (1)$$

where,

ACDI_i: average chronic daily dose intake by ingestion, in mg/kg/day unit.

BW: weight of body, in kg unit.

EF: exposure frequency, in days/year unit.

IR: ingestion rate, in L/day unit.

ED: exposure duration, in years unit.

C_w: average concentration of trace metals in water, in mg/L unit.

AT: average time (days).

Table 2 shows the key exposure parameters of the risk assessment analyses.

Both the carcinogenic (CR) and non-carcinogenic risks (NCR) are typically identified based on the risk assessment guidance recommendations of the USEPA. Non-carcinogenic risk were calculated through hazard quotient value (HQ), which reflects possible non-carcinogenic risks, applying Eq. (2) [30, 34].

$$Hazard\ Quotient\ (HQ_i) = \frac{ACDI_i}{RfD_i} \quad (2)$$

where,

ACDI_i is the average chronic daily dose intake, in mg/kg/day unit and The RfD is the oral reference dose of metallic compound in a specific condition (mg/kg/day); these parameters are taken from the US EPA's integrated risk information system [33, 34].

The index of hazard (HI), represents the sum of the HQs coming from all relevant pathways. HI was established to quantify the overall possible non-carcinogenic hazards provided by more than one route. If the HI less than or equal one, there may be a risk of non-carcinogenic impacts, while if HI more than 1 there may be a potential risk on human health or more research is required [34, 35].

$$Hazard\ Index(HI) = \sum_{i=1}^n HQ_i \quad (3)$$

where, RfD is derived from the risk-based concentration table. [34, 36].

To assess the carcinogenic risks (CR), the following equations were used.

$$Cancer\ Risk(CR_i) = ACDDi \times CSF \quad (4)$$

where, CSF is cancer slope factor (mg/kg/day) and CR denotes the cancer development likelihood induced by exposure to various types of carcinogenic chemicals over the period of an average population's lifetime.

Table 3 shows the quantities of oral slope factors unit risks for the three pollutants examined in this study.

When numerous TEs are taken into account, the total (CR) is used.; This quantity is computed by summing the CR of the carcinogenic substances under consideration. Total CR is calculated as follows [30]:

$$\text{Total (CR)} = \sum_{i=1}^n CR_i \quad (5)$$

Table 2. The key exposure parameters of the risk assessment analyses [30]

Exposure parameters	Symbols	Units	Non Carcinogenic		Carcinogenic
			Adult	Children	Adults and Children
Water Concentration	C	mg/L			
Frequency of Exposure	EF	days/year	365	365	365
Duration of Exposure	ED	years	30	6	70
Average Time	AT	days	ED×EF	ED×EF	ED×EF
Weight of Body	BW	kg	70	15	70
Rate of Ingestion	IR	L/day	2	1	2

Table 3. The quantities of oral slope factors unit risks for the three pollutants applied in this study

Exposure parameters	Cd	Pb	Cr	As	Ni	Fe
Oral RFD (mg/kg/day) ^a	5.00E-04	3.50E-03	3.00E-03	3.00E-04	2.00E-02	7.00E-01
Oral CSF (mg/kg/day)	0.38 ^b	0.0085 ^b	0.5 ^b	1.5 ^b	1.7 ^c	0 ^a

a: [30], b:[38], c: [39]

Table 4. Cancer risk (CR) classes according to the Delphi method [37]

Class	Impact	Value	Response
Class I	Extremely low risk	<E-06	Completely accept
Class II	Low risk	E-06, E-05	Ignore the risk
Class III	Low-medium risk	E-05,5E-05	Do not care about the risk
Class IV	Medium risk	5E-05, E-4	Care about the risk
Class V	Medium-high risk	E-04,5E-04	Concerned of risk and ready to invest,
Class VI	High risk	5E-04, E-03	Give importance to the risk and propose, suitable measures to mitigate it.
Class VII	Extremely high risk	risk >E-03	Refuse the risk, find a method to manage it.

2.4.1 Data preparation and analysis

The Excel software was applied for Data calculation. The descriptive statistics, including maximum, mean, standard deviation and coefficient of variation, Cluster analysis, and principal component analysis were used to assess metal source apportionment. SPSS V.24 software (IBM, USA) was used. This study also performed spatial analysis based on the numerous measured TEs and computed (CR) and non-carcinogenic risk (hazard index, HI) of TEs monitoring of each site and developed a set of maps about TEs, CR and HI using ArcGIS from Environmental Systems Research Institute (ESRI). Therefore, Geographic Information System (GIS) software application research in (HRA) has gained increasing interest and application [40].

3. RESULTS AND DISCUSSION

3.1 Concentration of trace elements

Table 5 provides the descriptive statistics of the average concentration of TEs. ArcGIS tool was applied in this study to model the spatially average concentration of TEs, as shown in

Depending on the USEPA's recommendations, the permissible or reasonable (CR) range is 10⁻⁶ to 10⁻⁴. Considerably, CR levels less than 10⁻⁶ reflect that the (CR) is assessed insignificant; Though, according to the most international organizations of regulatory, including the World Health Organization (WHO). CR is considered unacceptable for CR values greater than 10⁻⁴. Some researchers express CR based on the significant risk classification approach, in which the CR is categorized into 7 categories according to the Delphi method as shown in (Table 4), CR categorization gives better clarity and intelligible when assess the data [37].

The Figures 3-8. The results of the average TEs concentration showed that the percentage of monitored sites that exceed the desirable and recommended drinking water guidelines varied from one metal to another. Table 3 shows the results of (TEs) measurements obtained in water samples collected from the research region. In decreasing order, the average levels of tested metals were As > Cr > Fe > Pb > Cd > Ni. Data in Tables 5 shows that the (TEs) levels in (DTW) samples collected from the research area are following the decreasing order, Fe > As > Cr > Pb > Ni > Cd.

The results of the average Pb and As measurements showed that (100%) of monitored sites exceeded the united states environmental protection agency (USEPA), the World Health Organization (WHO), and Iraqi local standards (IQS) of drinking water criteria, respectively [24, 41].

The average Ni measurements showed that (72.3%, 0.0%, and 0.0%) of monitored sites exceeded the drinking water criteria, according to the (WHO), (IQS) and (USEPA) criteria respectively [24, 41, 42].

The average Fe and Cr measurements showed that (100%) of monitored sites comply with the drinking water, according to the (WHO), (USEPA) and (IQS) criteria [24, 41, 42].

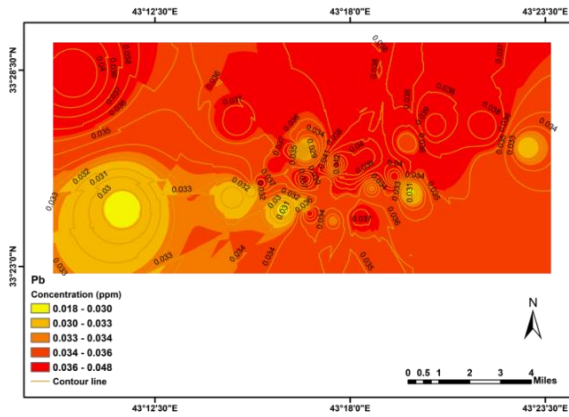


Figure 3. Average concentrations of Pb

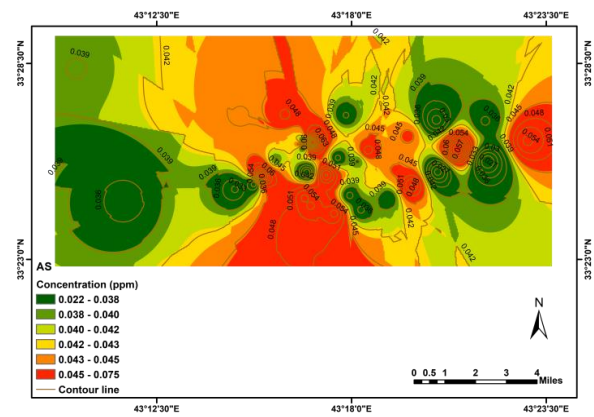


Figure 7. Average concentrations of As

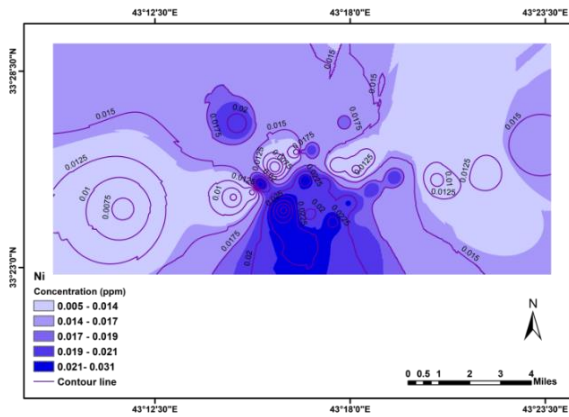


Figure 4. Average concentrations of Ni

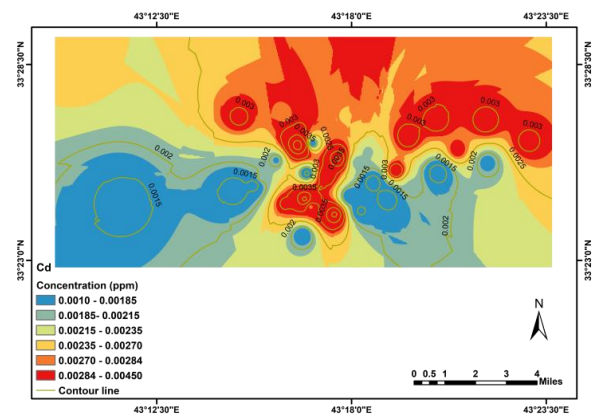


Figure 8. Average concentrations of Cd

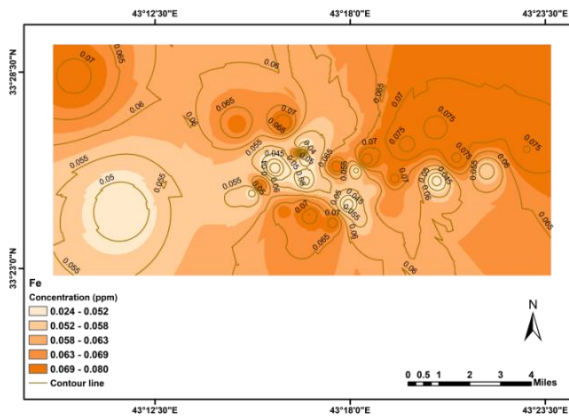


Figure 5. Average concentrations of Fe

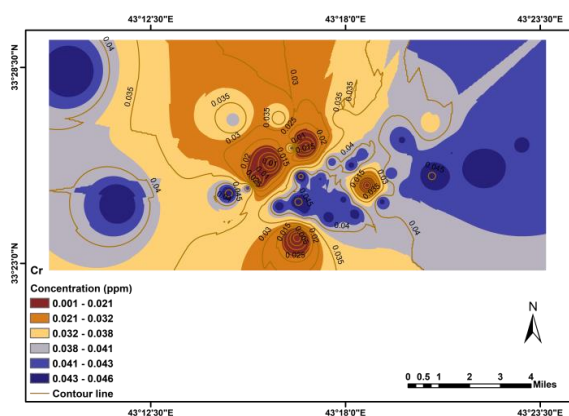


Figure 6. Average concentrations of Cr

The average Cd measurements showed that the percentage of monitored sites that comply with the drinking water guidelines were (100%, 61.2%, and 61.2%), according to the (WHO), (USEPA) and (IQS) respectively [24, 41, 42].

The results of Pb and As showed that all sites exceeded the (WHO), (USEPA) and (IQS) potable water criteria. The results of Ni show that stations (S2, S16, S18, S23, S24, S25, S26, S28, S30, and S34) were more than the USEPA and IQS drinking water guidelines, while Ni concentrations were within WHO guidelines in all stations.

The Fe and Cr concentrations were within WHO, USEPA, and IQS drinking water guidelines in all stations. The Cd measurements show that stations, including S2, S5, S6, S9, S10, S12, S14, S18, S20, S23, S26, S28, S30, and S36 exceeded the WHO drinking water guideline, while Cd concentrations were within USEPA and IQS guidelines in all stations. The descriptive statistic (minimum, maximum, average, and standard deviation) results regarding Pb were (0.019, 0.047, 0.0359, and 0.0052), respectively. The total average Pb concentration at all stations was more than the drinking water guidelines. The descriptive statistic (minimum, maximum, average, and standard deviation) results of Ni were (0.0050, 0.0310, 0.0166, and 0.0064), respectively. The total average Ni concentrations at all stations were within USEPA and IQS drinking water guidelines, but more than the WHO guideline. The descriptive statistic (minimum, maximum, average, and standard deviation) results of Fe were (0.0240, 0.0794, 0.0613, and 0.0138), respectively. The total average Fe concentration at all stations was within the drinking water guidelines. The descriptive statistic (minimum, maximum, average, and standard deviation) results of Cr were (0.0011, 0.0045, 0.0025, and 0.001), respectively. The total average Cr

concentration at all stations was within the drinking water guidelines .

The descriptive statistic (minimum, maximum, average, and standard deviation) results of As were (0.0224, 0.0748, 0.0436, and 0.0123), respectively. The total average As concentration at all stations exceeded the drinking water guidelines. The descriptive statistic (minimum, maximum, average, and standard deviation) results of Cd were (0.0100, 0.0450, 0.0244, and 0.0102), respectively, the total average Cd concentration at all stations was within the drinking water guidelines.

The results of the average Pb and As measurements showed

that (100%) of monitored sites exceeded the drinking water guidelines, according to the united states environmental protection agency (USEPA), the World Health Organization (WHO), and (IQS) for potable water uses guidelines [24, 41, 42].

Based on the comparative of the (WHO), (USEPA) and Iraqi standards drinking water criteria and the average measurements of the TEs, the (DTW) was polluted by Pb, Ni, As, and Cd .

Table 5 shows the descriptive statistics for (TEs) levels (mg/l) in comparison to the recommendations.

Table 5. Descriptive statistics of (TEs) measurements (mg/l) in comparison with criteria

TEs	.Min	.Max	Average TEs (Conc. \pm S.D) .	Drinking ^a	Drinking ^b	Drinking ^c
Pb	0.0190	0.0470	0.0359 \pm 0.0052	0.010	0.015	0.01
Ni	0.0050	0.0310	0.0166 \pm 0.0064	0.070	0.02	0.02
Fe	0.0240	0.0794	0.0613 \pm 0.0138	0.3	0.3	0.1
Cr	0.0011	0.0045	0.0025 \pm 0.001	0.050	0.10	0.05
As	0.0224	0.0748	0.0436 \pm 0.0123	0.01	0.01	0.01
Cd	0.0100	0.0450	0.0244 \pm 0.0102	0.003	0.005	0.005

(a): [24]; (b): [42]; (c): [41]

Table 6. Non carcinogenic risk (HQ) and (HI) of TEs for adults

Stations	Non Carcinogenic HQ Adult						
	Pb	Ni	Fe	Cr	As	Cd	HI
S1	3.35E-01	2.43E-02	2.90E-03	4.29E-01	3.70E+00	1.43E-01	4.64E+00
S2	3.10E-01	3.00E-02	2.83E-03	3.73E-01	4.30E+00	1.77E-01	5.20E+00
S3	3.02E-01	2.14E-02	3.05E-03	3.54E-01	4.62E+00	1.60E-01	5.46E+00
S4	3.10E-01	2.57E-02	2.35E-03	3.44E-01	3.40E+00	1.54E-01	4.24E+00
S5	3.27E-01	1.86E-02	3.19E-03	3.50E-01	2.75E+00	1.83E-01	3.63E+00
S6	3.18E-01	2.00E-02	2.98E-03	3.96E-01	3.39E+00	1.83E-01	4.31E+00
S7	2.37E-01	1.00E-02	1.87E-03	4.24E-01	3.30E+00	6.86E-02	4.04E+00
S8	2.53E-01	1.29E-02	1.95E-03	4.06E-01	2.97E+00	7.43E-02	3.72E+00
S9	3.84E-01	1.14E-02	2.95E-03	4.16E-01	4.34E+00	2.57E-01	5.41E+00
S10	3.67E-01	1.43E-02	3.05E-03	4.04E-01	3.35E+00	2.34E-01	4.37E+00
S11	3.35E-01	1.57E-02	3.24E-03	4.06E-01	4.68E+00	1.20E-01	5.56E+00
S12	2.86E-01	2.00E-02	3.15E-03	4.11E-01	4.36E+00	1.89E-01	5.27E+00
S13	3.02E-01	2.00E-02	3.11E-03	4.10E-01	6.27E+00	1.71E-01	7.17E+00
S14	2.61E-01	2.43E-02	3.07E-03	4.10E-01	5.21E+00	1.77E-01	6.09E+00
S15	2.53E-01	1.00E-02	2.22E-03	4.39E-01	3.09E+00	5.71E-02	3.85E+00
S16	3.10E-01	3.86E-02	2.90E-03	3.52E-02	6.26E+00	1.20E-01	6.76E+00
S17	3.02E-01	7.14E-03	1.46E-03	2.38E-02	3.70E+00	1.03E-01	4.13E+00
S18	2.86E-01	3.00E-02	2.17E-03	4.10E-01	5.47E+00	1.94E-01	6.39E+00
S19	3.35E-01	1.29E-02	1.99E-03	4.16E-01	3.69E+00	1.14E-01	4.57E+00
S20	3.43E-01	2.86E-02	2.91E-03	4.06E-01	4.35E+00	1.94E-01	5.33E+00
S21	3.02E-01	1.29E-02	1.73E-03	4.31E-01	2.46E+00	6.29E-02	3.27E+00
S22	2.86E-01	1.57E-02	2.13E-03	4.27E-01	2.33E+00	9.71E-02	3.16E+00
S23	2.53E-01	3.00E-02	2.78E-03	4.40E-01	5.23E+00	2.34E-01	6.19E+00
S24	3.27E-01	3.43E-02	1.74E-03	4.36E-01	2.65E+00	8.00E-02	3.53E+00
S25	2.86E-01	3.14E-02	1.67E-03	4.13E-01	3.34E+00	8.57E-02	4.16E+00
S26	3.02E-01	4.14E-02	2.33E-03	4.01E-01	5.19E+00	1.94E-01	6.13E+00
S27	2.37E-01	2.14E-02	2.51E-03	4.02E-01	5.15E+00	1.20E-01	5.93E+00
S28	2.29E-01	4.43E-02	2.82E-03	4.22E-01	4.50E+00	1.77E-01	5.37E+00
S29	3.18E-01	2.71E-02	3.07E-03	4.17E-01	5.21E+00	1.60E-01	6.13E+00
S30	2.69E-01	3.29E-02	2.95E-03	4.19E-01	5.25E+00	2.34E-01	6.21E+00
S31	3.10E-01	2.57E-02	2.17E-03	4.18E-01	3.36E+00	8.00E-02	4.20E+00
S32	2.94E-01	2.14E-02	2.63E-03	4.14E-01	3.44E+00	6.29E-02	4.23E+00
S33	2.69E-01	2.86E-02	2.28E-03	2.38E-02	4.08E+00	6.29E-02	4.46E+00
S34	2.86E-01	3.43E-02	2.70E-03	2.57E-02	4.77E+00	8.57E-02	5.21E+00
S35	2.69E-01	2.86E-02	2.23E-03	3.71E-02	7.12E+00	8.57E-02	7.55E+00
S36	1.55E-01	2.63E-02	9.80E-04	1.05E-02	2.13E+00	2.17E-01	2.54E+00
Min.	1.55E-01	7.14E-03	9.80E-04	1.05E-02	2.13E+00	5.71E-02	2.54E+00
Max.	3.84E-01	4.43E-02	3.24E-03	4.40E-01	7.12E+00	2.57E-01	7.55E+00
Avg.	2.93E-01	2.37E-02	2.50E-03	3.44E-01	4.15E+00	1.42E-01	4.96E+00
S.D	4.21E-02	9.12E-03	5.62E-04	1.44E-01	1.17E+00	5.83E-02	1.18E+00

Table 7. Non carcinogenic risk (HQ) and (HI) of TEs for children

Stations	Non Carcinogenic HQ Child						HI
	Pb	Ni	Fe	Cr	As	Cd	
S1	7.81E-01	5.67E-02	6.77E-03	1.00E+00	8.64E+00	3.33E-01	10.82271
S2	7.24E-01	7.00E-02	6.61E-03	8.71E-01	1.00E+01	4.13E-01	12.12991
S3	7.05E-01	5.00E-02	7.11E-03	8.27E-01	1.08E+01	3.73E-01	12.74028
S4	7.24E-01	6.00E-02	5.49E-03	8.02E-01	7.93E+00	3.60E-01	9.885345
S5	7.62E-01	4.33E-02	7.45E-03	8.18E-01	6.42E+00	4.27E-01	8.479776
S6	7.43E-01	4.67E-02	6.96E-03	9.24E-01	7.91E+00	4.27E-01	10.05921
S7	5.52E-01	2.33E-02	4.36E-03	9.89E-01	7.69E+00	1.60E-01	9.418325
S8	5.91E-01	3.00E-02	4.54E-03	9.47E-01	6.93E+00	1.73E-01	8.678786
S9	8.95E-01	2.67E-02	6.89E-03	9.71E-01	1.01E+01	6.00E-01	12.63387
S10	8.57E-01	3.33E-02	7.12E-03	9.42E-01	7.82E+00	5.47E-01	10.20921
S11	7.81E-01	3.67E-02	7.56E-03	9.47E-01	1.09E+01	2.80E-01	12.96361
S12	6.67E-01	4.67E-02	7.35E-03	9.60E-01	1.02E+01	4.40E-01	12.29908
S13	7.05E-01	4.67E-02	7.27E-03	9.56E-01	1.46E+01	4.00E-01	16.73731
S14	6.10E-01	5.67E-02	7.16E-03	9.58E-01	1.22E+01	4.13E-01	14.20073
S15	5.91E-01	2.33E-02	5.19E-03	1.02E+00	7.20E+00	1.33E-01	8.977227
S16	7.24E-01	9.00E-02	6.76E-03	8.22E-02	1.46E+01	2.80E-01	15.78358
S17	7.05E-01	1.67E-02	3.40E-03	5.56E-02	8.62E+00	2.40E-01	9.643088
S18	6.67E-01	7.00E-02	5.07E-03	9.58E-01	1.28E+01	4.53E-01	14.90915
S19	7.81E-01	3.00E-02	4.64E-03	9.71E-01	8.60E+00	2.67E-01	10.6539
S20	8.00E-01	6.67E-02	6.79E-03	9.47E-01	1.02E+01	4.53E-01	12.42963
S21	7.05E-01	3.00E-02	4.04E-03	1.01E+00	5.73E+00	1.47E-01	7.625848
S22	6.67E-01	3.67E-02	4.96E-03	9.96E-01	5.44E+00	2.27E-01	7.375331
S23	5.91E-01	7.00E-02	6.49E-03	1.03E+00	1.22E+01	5.47E-01	14.44102
S24	7.62E-01	8.00E-02	4.05E-03	1.02E+00	6.18E+00	1.87E-01	8.228586
S25	6.67E-01	7.33E-02	3.89E-03	9.64E-01	7.80E+00	2.00E-01	9.708816
S26	7.05E-01	9.67E-02	5.43E-03	9.36E-01	1.21E+01	4.53E-01	14.30757
S27	5.52E-01	5.00E-02	5.85E-03	9.38E-01	1.20E+01	2.80E-01	13.84892
S28	5.33E-01	1.03E-01	6.57E-03	9.84E-01	1.05E+01	4.13E-01	12.53053
S29	7.43E-01	6.33E-02	7.15E-03	9.73E-01	1.22E+01	3.73E-01	14.31628
S30	6.29E-01	7.67E-02	6.88E-03	9.78E-01	1.22E+01	5.47E-01	14.48173
S31	7.24E-01	6.00E-02	5.07E-03	9.76E-01	7.84E+00	1.87E-01	9.796033
S32	6.86E-01	5.00E-02	6.14E-03	9.67E-01	8.02E+00	1.47E-01	9.877907
S33	6.29E-01	6.67E-02	5.32E-03	5.56E-02	9.51E+00	1.47E-01	10.41441
S34	6.67E-01	8.00E-02	6.31E-03	6.00E-02	1.11E+01	2.00E-01	12.14691
S35	6.29E-01	6.67E-02	5.21E-03	8.67E-02	1.66E+01	2.00E-01	17.61022
S36	3.62E-01	6.13E-02	2.29E-03	2.44E-02	4.98E+00	5.07E-01	5.934709
Min.	3.62E-01	1.67E-02	2.29E-03	2.44E-02	4.98E+00	1.33E-01	5.934709
Max.	8.95E-01	1.03E-01	7.56E-03	1.03E+00	1.66E+01	6.00E-01	17.61022
Avg.	6.84E-01	5.52E-02	5.84E-03	8.04E-01	9.68E+00	3.31E-01	11.56388
S.D	9.82E-02	2.13E-02	1.31E-03	3.36E-01	2.73E+00	1.36E-01	2.746053

The findings revealed that the tap water was unfit for human consumption. The aging and degraded network might be responsible for the pollution.

This pollution could be highly attributed to discharging untreated wastewater from many activities (residential, medical, industrial), into the Euphrates River, where Ramadi city is located. In fact, Ramadi city has no wastewater treatment plant, so agricultural drainage, illegal disposal of garbage, and solid waste into Euphrates River banks, where some solid waste including damaged cars and metals due to military operation has increased this pollution.

3.2 Health risk of trace elements

3.2.1 Non carcinogenic risk

Many researchers, however, realize that estimating health risks related to trace elements based on (TEs) measurements is insufficient and it must be evaluated using other indices [43]. In this study, determined the Cancer Risk and hazard quotient (HQ) were used to determine the (NCR) as (HI) and (CR) of trace elements. Table 6, Figure 9, and Figure 10 summarize the predicted non-carcinogenic risk HQ of trace elements for adults who use tap water in RC. According to Table 6, most

HQ trace element values were less than 1 except (As), which is more than 1. HQ of trace element values were in order of As (4.15) > Cr (0.344) > Pb (0.293) > Cd (0.142) > Ni (0.0237) > Fe (0.0025), but (HI) more than (1) due to the high value of (HI) of As, which represents the major (NCR) contributor of adults [25, 34]. The results show that HQ of As values for adults represent the major (NCR) contributor. According to the data of Table 7, Figure 9, and Figure 10, there could be a potential risk on adults' health, so monitoring and management programs are required [44].

Table 7, Figure 11 and Figure 12 summarize the predicted non carcinogenic risk (HQ) of trace elements for children. According to Table 7, most HQ trace element values were less than one except (As), which is more than 1. The average HQ trace element values were in order of As (9.68) > Cr (0.803) > Pb (0.683) > Cd (0.331) > Ni (0.055) > Fe (0.0058), but HI more than 1, indicating potential risk on human health [34, 35]. The results of Table 7 also show that HQ of As values for children represent the major (NCR) contributor.

The high concentrations, (NCR) and (CR) values of As for both adults and teenagers in taps drinking water of RC are probably generated from anthropogenic activities at the study area, including mainly fossil combustion and application of

arsenic-containing fertilizers and pesticides for agricultural purposes natural origins (soil and rocks weathering) [45].

Tables 6 and 7 and Figures 9-12 also demonstrate that children's HI values are roughly twice as high as HI values for adults.

The high (HI) of As represents an extremely high risk to children's health which required strict monitoring and management program are required [44].

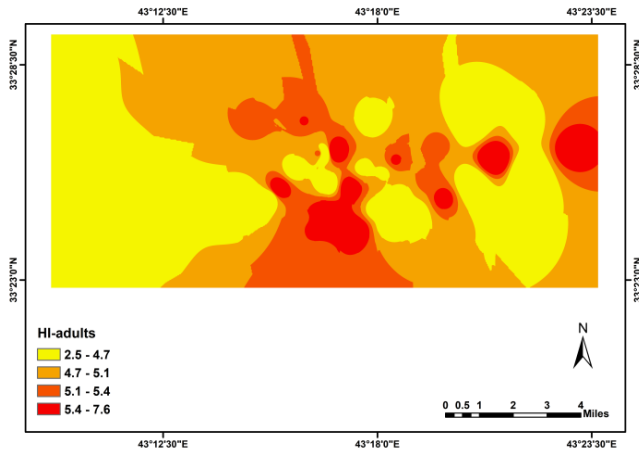


Figure 9. Average non-carcinogenic risk (NCR, HQs) and Hazardous Index (HI) of TEs for adults

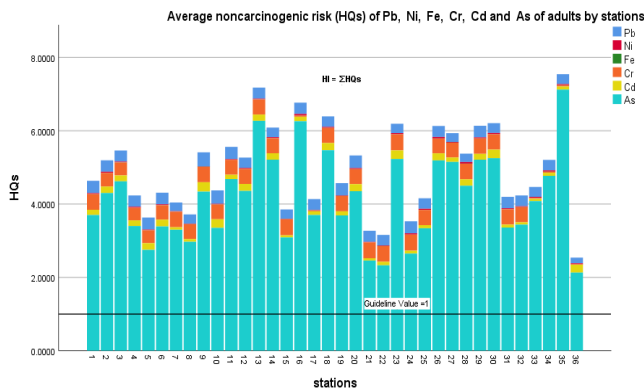


Figure 10. Average non-carcinogenic risk (NCR, HQs) and Hazardous Index (HI) of TEs for adults

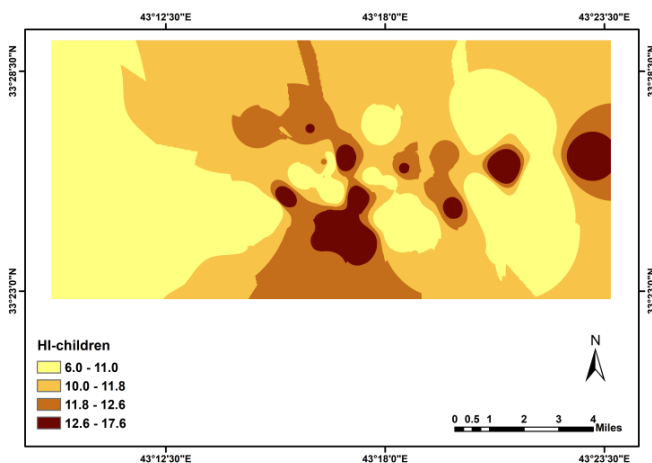


Figure 11. Average non-carcinogenic risk (NCR, HQs) and Hazardous Index (HI) of TEs for children

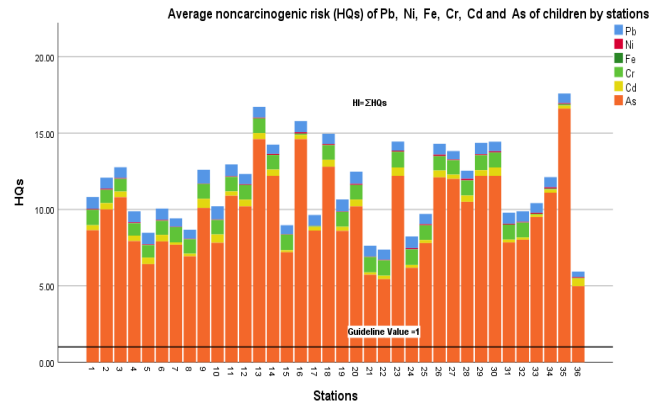


Figure 12. Average Non-carcinogenic risk (NCR, HQs) and Hazardous Index (HI) of TEs for children

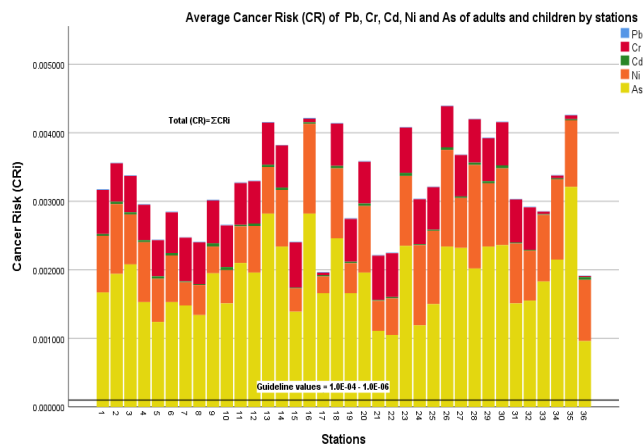


Figure 13. Average carcinogenic risk (CR_i) and total carcinogenic risk (CR) of TEs for adults and children

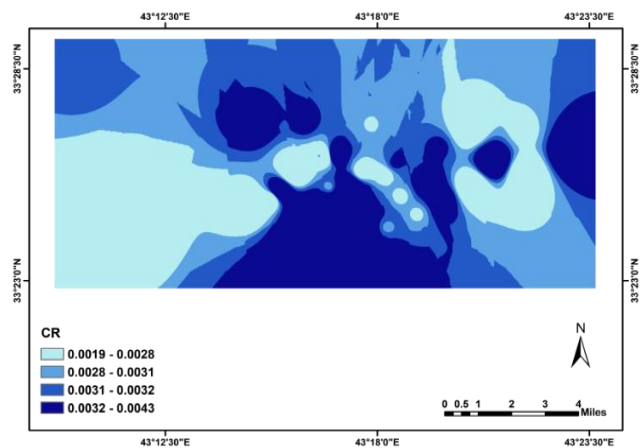


Figure 14. Average carcinogenic risk (CR_i) and total carcinogenic risk (CR) of TEs for adults and children

3.2.2 Carcinogenic risk

The safe value for (CR) exposed by a (TEs) is 1.00E-06, which means the presence of one cancer case every 1,000,000 people [44]. Table 8, Figures 13 and 14 display the estimated carcinogenic risk CR values of Cd, Cr, As, Ni, and Pb elements in the section study area regarding adults and children. The estimated CR falls within the E-03 to E-06 range. The average CR of trace elements is listed in declining order as follows: AS (1.84E-03) > Ni (7.89E-04) > Cr (5.03E-04) > Cd (2.66E-05) >

Pb (8.60E-06). The total average carcinogenic risk was calculated to be 3.19E-03 per capita. As result, the likelihood of developing cancer cases is one in a thousand. Depending on the Classes presented in Table 4, the carcinogenic risk of As is classified as Class VII (extremely high risk), which requires refusing the risk and finding a method to manage it. The carcinogenic risk of Ni and Cr were classified as Class VI (high risk), which require giving importance to the risk and proposing suitable measures to mitigate it. The carcinogenic

risk of Cd is classified as Class III (low-medium risk), which does not require care about the risk. The carcinogenic risk of Pb is classified as Class II (low risk), which does not need any care about the risk. The carcinogenic risk of Cd and Pb were ranged within the recommended acceptable range (E-04-E-06), while As, Cr, and Ni were not complying with the recommended by [44], safe value for (CR). The total average CR was Class VII (extremely high risk), which require Refuse the risk and finding a method to manage it [44].

Table 8. Carcinogenic risk (CR) and (Total CR) for adults and children

Stations	Carcinogenic Risk (CR)					Total Risk
	Pb	Cr	As	Cd	Ni	
S1	9.96E-06	6.43E-04	1.67E-03	2.71E-05	8.26E-04	3.17E-03
S2	9.23E-06	5.60E-04	1.94E-03	3.37E-05	1.02E-03	3.56E-03
S3	8.99E-06	5.31E-04	2.08E-03	3.04E-05	7.29E-04	3.38E-03
S4	9.23E-06	5.16E-04	1.53E-03	2.93E-05	8.74E-04	2.96E-03
S5	9.71E-06	5.26E-04	1.24E-03	3.47E-05	6.31E-04	2.44E-03
S6	9.47E-06	5.94E-04	1.53E-03	3.47E-05	6.80E-04	2.84E-03
S7	7.04E-06	6.36E-04	1.48E-03	1.30E-05	3.40E-04	2.48E-03
S8	7.53E-06	6.09E-04	1.34E-03	1.41E-05	4.37E-04	2.40E-03
S9	1.14E-05	6.24E-04	1.95E-03	4.89E-05	3.89E-04	3.03E-03
S10	1.09E-05	6.06E-04	1.51E-03	4.45E-05	4.86E-04	2.66E-03
S11	9.96E-06	6.09E-04	2.10E-03	2.28E-05	5.34E-04	3.28E-03
S12	8.50E-06	6.17E-04	1.96E-03	3.58E-05	6.80E-04	3.30E-03
S13	8.99E-06	6.14E-04	2.82E-03	3.26E-05	6.80E-04	4.16E-03
S14	7.77E-06	6.16E-04	2.34E-03	3.37E-05	8.26E-04	3.83E-03
S15	7.53E-06	6.59E-04	1.39E-03	1.09E-05	3.40E-04	2.41E-03
S16	9.23E-06	5.29E-05	2.82E-03	2.28E-05	1.31E-03	4.21E-03
S17	8.99E-06	3.57E-05	1.66E-03	1.95E-05	2.43E-04	1.97E-03
S18	8.50E-06	6.16E-04	2.46E-03	3.69E-05	1.02E-03	4.14E-03
S19	9.96E-06	6.24E-04	1.66E-03	2.17E-05	4.37E-04	2.75E-03
S20	1.02E-05	6.09E-04	1.96E-03	3.69E-05	9.71E-04	3.59E-03
S21	8.99E-06	6.47E-04	1.11E-03	1.19E-05	4.37E-04	2.21E-03
S22	8.50E-06	6.40E-04	1.05E-03	1.85E-05	5.34E-04	2.25E-03
S23	7.53E-06	6.60E-04	2.35E-03	4.45E-05	1.02E-03	4.08E-03
S24	9.71E-06	6.54E-04	1.19E-03	1.52E-05	1.17E-03	3.04E-03
S25	8.50E-06	6.20E-04	1.50E-03	1.63E-05	1.07E-03	3.22E-03
S26	8.99E-06	6.01E-04	2.34E-03	3.69E-05	1.41E-03	4.39E-03
S27	7.04E-06	6.03E-04	2.32E-03	2.28E-05	7.29E-04	3.68E-03
S28	6.80E-06	6.33E-04	2.02E-03	3.37E-05	1.51E-03	4.20E-03
S29	9.47E-06	6.26E-04	2.34E-03	3.04E-05	9.23E-04	3.93E-03
S30	8.01E-06	6.29E-04	2.36E-03	4.45E-05	1.12E-03	4.16E-03
S31	9.23E-06	6.27E-04	1.51E-03	1.52E-05	8.74E-04	3.04E-03
S32	8.74E-06	6.21E-04	1.55E-03	1.19E-05	7.29E-04	2.92E-03
S33	8.01E-06	3.57E-05	1.83E-03	1.19E-05	9.71E-04	2.86E-03
S34	8.50E-06	3.86E-05	2.15E-03	1.63E-05	1.17E-03	3.38E-03
S35	8.01E-06	5.57E-05	3.21E-03	1.63E-05	9.71E-04	4.26E-03
S36	4.61E-06	1.57E-05	9.60E-04	4.13E-05	8.94E-04	1.92E-03
Min.	4.61E-06	1.57E-05	9.60E-04	1.09E-05	2.43E-04	1.92E-03
Max.	1.14E-05	6.60E-04	3.21E-03	4.89E-05	1.51E-03	4.39E-03
Avg.	8.60E-06	5.03E-04	1.84E-03	2.66E-05	7.89E-04	3.19E-03
S.D	1.40E-06	2.28E-04	5.39E-04	1.12E-05	3.19E-04	7.28E-04

4. CONCLUSION

In this research, the possible health risks of (DTW) in Ramadi city were assessed. As, Cd, Cr, Ni, Pb and Fe concentrations met standards of drinking water. These concentrations were under allowed levels of the maximum values recommended by the WHO, USEPA and IQS guidelines.

The results regarding Pb and As show that all stations were exceed the allowed levels compared with the (WHO), (USEPA) and (IQS) drinking water guidelines. The results of Ni also show that stations (S2, S16, S18, S23, S24, S25, S26, S28, S30

and S34) were more than the USEPA and IQS drinking water guidelines, while Ni concentrations were within WHO guidelines in all stations.

The Fe and Cr concentrations were complying with WHO, USEPA and IQS drinking water guidelines in all stations. The Cd measurements show that stations (S2, S5, S6, S9, S10, S12, S14, S18, S20, S23, S26, S28, S30, and S36) have exceeded the WHO drinking water guideline, while Cd concentrations were within USEPA and IQS guidelines in all stations. Most HQ values of (TEs) were less than 1 except (As), which is more than 1. The HQ values of trace elements were followed the descending order of As (4.15) > Cr (0.344) > Pb (0.293) >

Cd (0.142) > Ni (0.0237) > Fe (0.0025). However, HI was more than 1 so that it could be a potential risk on the human beings' health.

The risk of carcinogenic related to As is classified as Class VII (extremely high risk), which require to refuse the risk and find a method to manage it. The carcinogenic risk of Ni and Cr were classified as Class VI (high risk), which need to pay attention to the risk and propose suitable measures to mitigate it. The carcinogenic risk of Cd is classified as Class III (low-medium risk), which do not require care about the risk. on the other hand, the carcinogenic risk of Pb is classified as Class II (low risk), which do not need any care about the risk. The carcinogenic risk of Cd and Pb were ranged within the recommended acceptable levels (E-04-E-06), while As, Cr and Ni were not complied with those recommended by USEPA [44], safe value for (CR). The total average CR was Class VII (extremely high risk), which requires to refuse the risk and find a method to manage it. Significantly, there was CR in (DTW) of Ramadi city so that local governments should be concerned about. Our recommendations to decrease levels of pollution in RC's taps drinking water sources include,

1) Establishment wastewater treatment plants according to environmental and geographical requirements and prevent any discharge of wastewater and solid waste disposal in water resources.

2) Replacement the old network and implementation new network.

3) Building an effective program to monitor and manage water resources.

4) Efficiency enhancement of the current drinking water treatment projects.

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