Mesopotemia Environmental journal
ISSN 2410-2598
journal homepage:www.bumej.com

Risk assessment of heavy metals in tap drinking water in different age group; in Baghdad city, Iraq

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To cite this article:

Risk assessment of heavy metals in tap drinking water in different age group; in Baghdad city, Iraq. *Mesop. environ. j.*, 2018, Vol. 4, No.2, pp. 89-102

Received date: 7/8/2017 accepted date: 12/12/2017 published date: 15/3/2018

Abstract

The heavy metals such as lead Pb, copper Cu and iron Fe that found in drinking water resources causes toxicity and biological effects which is hazardous to human health. Kidney damage, headache and brain are the chronic effects on human resulting from long term exposure. In this study, samples are taken from six stations distributed in three places in Baghdad city from tap drinking water for the months of March to December 2014. The first two stations located in Al-Kadmyai area, the 3rd and 4th located in Al- Doora while the last two stations located in Al-Amryai area. Carcinogenic and non-carcinogenic risk assessment of lead, copper, and iron are implemented in order to show the probable cancer risk for inhabitants in Baghdad city. The determinations consist of the chronic daily intake for each pollutant, hazard quotient and total risk for adults' men, women and children, using Environmental Protection Agency EPA equations, ingestion, and dermal are the exposure pathways. The averages non- carcinogenic chronic daily intake through ingestion of water CDI_{ing} and through dermal adsorption CDI_{derm} are as the following order: Pb>Cu>Fe for adult men, adult women and children respectively. The CDI_{ing} and CDI_{derm} order for the three age groups is: children>adult women>adult men for all stations. The hazard index *HI* for ingestion and dermal contact of drinking water in six stations is less than 1, this means that population in Baghdad city which consumed tap water are in a safe place. The carcinogenic risk order through ingestion for lead is adult women>adult men>children in all stations. For all stations the values of carcinogenic risk CR_{ing} are between 10^{-6} and

10^{-4}, it can be said that all stations are with the agreeable limit for carcinogenic risk for lead, so the population in three areas in Baghdad city is also in a safe area.

Key words:

Toxicity, Heavy metals in drinking water, Chronic daily intake, Environmental health, Age groups.

Introduction

Heavy metals or trace elements are the metallic elements in the periodic table have a great density and atomic weight as compared with water. Very low concentration of heavy metals are toxic and damaging. Friendly heavy metals are the amount of metals that body needs. The heavy metals enter the body through different pathways: inhalation, ingestion and skin absorption [1].

According to metal density, there are two types: metals which have densities >7 gr/cm^3 are called heavy metals, the other are light having densities < 4 gr/cm^3. The number of heavy metals are over fifty, seventeen of them are toxic. There are different levels of toxicity depending on metal type. Poisoning heavy metals in drinking water are lead, iron, cadmium copper, zinc, chromium etc. [2].

Heavy metals cancers are related with neurological disorders, kidney disorders and tooth decay as indicated by the epidemiological studies [3]. Low or high concentration of physio-chemical elements in drinking water are affecting directly on human or indirectly [4].

In tap water the concentration of free metal in drinking water is as guideline for understanding the part of any pollutant [5]. Heavy metals is an environmental toxicant, but heavy metals existing normally in nature are not toxic because of its low concentrations [6].

Environment geology is related with chronic diseases and serious health problems. Water contamination plays the main role in contaminate our environment. All the particles that founded in air are going to the rivers by rainwater collectors, also the industrial effluents and sewage are discharged to the rivers or streams which are the main sources of human drinking water [7].

The concentration of heavy metals in the milk of mothers who drink from tap water in Al-Hilla city was studied. The heavy metals concentration in the milk of mothers who drinking from bottled water is below than the heavy metals concentration the milk of mothers who drinking from river or tap water. This means that rivers and tap water are polluted with heavy metals and show the relationship between heavy metals concentration and human health. These heavy metals are come from Al- Hilla textile big factory by drawn its waste in Shutt Al-Hilla (source of drinking water in Al-Hilla city) [8].

Stages of risk analysis are: hazard identification, risk assessment and risk evaluation to explain the basic information for risk management [9].

In spite of acceptable levels of heavy metals in drinking water biomarkers of trace metal are used to discover the accumulative heavy metals in human tissue. Toenail is the best biomarkers among the blood, urine and hair because of their growth [10].

Research Significant

The main goal of this study is explained the impact of the contaminated drinking water with heavy metals (Pb, Cu and Fe) on human health. The health risk assessment of cancer diseases and non-cancerous diseases is also evaluated for three age group: adult men, adult women and children in six stations distributed in Baghdad city. Then the computed values compared with the drinking water standards which recommended by international organizations. This approach receives little attention by many Iraqis researchers, so this study provides primary information of diverse heavy metals in Baghdad city. The results from this study can be used in future planning and monitoring drinking water quality plants and minimizing the exposure at optimum levels.

Materials and Methods

Study area

The study area (the residential areas with its sampling stations) in Baghdad city are listed in table 1.

Table 1 The study area and its residential district [11].

No.	Residential district	Sampling station
1	Kazimiyah	427 (St. 1, 2),Al- Karama treatment plant
2	Al- Dora	826(St.3) and 834(St.4), Al-Dora treatment plant
3	Amiriya	638 (St.5) and 636 (St.6), Al-Karkh treatment plant

Figure 1 Study stations of water samples in Baghdad city [11].

Risk Assessment

Heavy metals have multiple pathways to enter the human body such as ingestion, inhalation and dermal contact [4].Chronic daily intake *CDI* is calculated using exposure equations [12].

1. Drinking water ingestion

$$CDI_{ing} = \frac{CW * IR * EF * ED}{BW * AT} \quad \ldots 1$$

2. Dermal contact with water

$$CDI_{derm} = \frac{CW * SA * PC * ET * EF * ED * CF}{BW * AT} \quad \ldots 2$$

Where CDI_{ing} and CDI_{derm} are chronic daily intakes through ingestion dermal absorption of water (µg/kg/d). Table 2 listed the estimating values of human health risk assessment through ingestion dermal absorption contacts provided by EPA, which used in this study because there was no exact information about the residents in Baghdad city.

The processes of estimating is the probability of existence of any magnitude of unacceptable health effects for limited time period or it's the relation between the hazard and exposure [13]. Equations 1 and 2 are used to determine the doses exposure.

Table 2 Parameters for estimating exposure assessment of heavy metals in water samples used in the present study.

Exposure factors	Unit	Values (adult/men)	Values (adult/women)	Values (children)
Concentration of metals in water (C_{water})	µg/L	-	-	-
Water ingestion rate (*IR*)[1]	L/day	2.3	2.3	1.5
Exposure frequency (*EF*)[1]	days/ year	360	360	350
Exposure duration (*ED*)[1]	year	30	30	6
Average body weight (*BW*)[1]	kg	78	65	15
Averaging time (*AT*)[1] For non-carcinogens, *AT* = *ED* × 365 days; For carcinogens, *AT* = 70 (human life expectancy) × 365 days.	days	 10,950 25,550	 10,950 25,550	 2,190 25,550
Exposed skin area (*SA*)[2]	cm^2	20,900	20,900	9,000
Exposure time (*ET*)[3]	h/day	0.6	0.6	0.6

Unit conversion factor(*CF*)	L/cm^3	0.001	0.001	0.001
Dermal permeability coefficient (*Kp*)[4]	cm/h			
Pb		0.0001	0.0001	0.0001
Cu		0.001	0.001	0.001
Fe		0.001	0.001	0.001

1. [12]. 2. [14]. 3. [15]. 4. [16]

To explain the carcinogens and non-carcinogens effects on human health the ingestion or dermal hazard quotient *HQ* (unit less), is computed using equation 3 with the oral (ingestion) or dermal reference dose *RfD* (µg/kg/d)which is listed in table 3 [13].

$$HQ_{\frac{ing}{derm}} = \frac{CDI_{\frac{ing}{derm}}}{RfD_{\frac{ing}{derm}}} \quad \ldots 3$$

Hazard index *HI* (unit less) for multiple substances and for multiple pathways giving by EPA to evaluate non-carcinogenic effect [12]:

$$HI = \sum HQ \quad \ldots 4$$

If *HI* > 1 this showed the adverse effect of heavy metals on human health [13]. The carcinogenic risk factor of chemical pollutants *CR* (unit less) is as below [12].

$$CR = CDI * SF \qquad when\ CDI \times SF < 0.01 \quad \ldots 5$$

$$CR = 1 - \exp(-CDI * SF) \qquad otherwise \quad \ldots 6$$

Where *SF* is carcinogenic slope factor listed in table 4. The acceptable *CR* range is from 10^{-6} to 10^{-4} as recommended by United States Environmental Protection Agency, and if $CR < 10^{-6}$, cancer risks are neglected, cancer risks are unacceptable if $CR > 10^{-4}$ [12].

Table 3 Reference dose [13].

Heavy metal	RfD_{ing} (µg/kg/d)	RfD_{derm} (µg/kg/d)
Pb	1.4	0.42
Cu	40	8
Fe	700	140

Table 4 Carcinogenic slope factor for lead [13].

Pathway	*SF* $(\mu g/g/d)^{-1}$
Oral	$8.5*10^{-3}$

Results and discussion

Heavy metals concentrations in tap water for the six stations [11] are listed in table 5.

Table 5 Statistics of heavy metals for tap water in study stations from March to December2014 [11].

Station	Statistics	Heavy metal concentration(mg/L)		
		Pb	Cu	Fe
St.1	Range	ND*-0.004	ND-0.01	ND-0.36
	Mean	0.002	0.005	0.18
St.2	Range	ND-0.01	ND-0.053	ND-0.38
	Mean	0.005	0.026	0.19
St.3	Range	ND-0.003	ND-0.01	ND-0.3
	Mean	0.0015	0.005	0.15
St.4	Range	ND-0.01	ND-0.05	ND-0.3
	Mean	0.005	0.025	0.15
St.5	Range	ND-0.003	ND-0.006	ND-0.3
	Mean	0.0015	0.003	0.15
St.6	Range	ND-0.001	ND-0.002	ND-0.3
	Mean	0.0005	0.001	0.15

ND*- not detected, Statistical tests for data have been done by using SPSS.

Concentration of Cu and Pb in water range from no detectable to detectable (0.01-0.053mg/l) in spring season respectively. So the differences between stations for Pb and Cu were not significant. The metals concentration in river water which is considered the main source of raw water for purification projects in Iraq will not affected by seasonal changes .as well as old residue in water from battery factory. The concentration of Pb and Cu were accepted according to Iraqi specification (417) and USEPA. Iron ion concentration in water ranged from no detected and detectable value (0.38mg/l) in spring season which has exceeded the maximum acceptable limit (0.3mg/l) (Iraqi specification 417) [11].

The results of health risk analysis for heavy metals in tap water samples in all stations through ingestion and dermal pathways from March to December 2014 (non-carcinogenic and carcinogenic effects) are in tables' 6-a1, 6-a2 and 6-b. For all stations the non- carcinogenic CDI_{ing} and CDI_{derm} average values order for adult men, adult women and children are Pb>Cu>Fe respectively, the CDI_{ing} and CDI_{derm} order for the three age groups is: children>adult women>adult men for all stations.

Table 6-a1 Chronic daily intake for heavy metals in tap water samples in different stations through ingestion pathway from March to December2014 (non-carcinogenic).

Station	Statistics	Pb			Cu			Fe		
		$CDI_{non-carcinogenic}$(µg/kg/d)			$CDI_{non-carcinogenic}$(µg/kg/d)			$CDI_{non-carcinogenic}$(µg/kg/d)		
		Adult men	Adult women	Children	Adult men	Adult women	Children	Adult men	Adult women	Children
St.1	Range Mean	ND* - 0.116 0.058	ND – 0.137 0.070	ND – 0.384 0.192	ND - 0.291 0.146	ND- 0.349 0.175	ND -0.960 0.480	ND–10.476 5.238	ND-12.564 6.282	ND-34.524 17.262
St.2	Range Mean	ND - 0.291 0.146	ND- 0.349 0.175	ND -0.960 0.480	ND-1.542 0.757	ND-1.850 0.907	ND-5.083 2.493	ND-11.058 5.529	ND-13.262 6.631	ND-36.442 18.221
St.3	Range Mean	ND-0.087 0.044	ND-0.105 0.052	ND-0.288 0.144	ND - 0.291 0.146	ND- 0.349 0.175	ND -0.960 0.480	ND-8.730 4.365	ND-10.470 5.235	ND-28.770 14.385
St.4	Range Mean	ND - 0.291 0.146	ND- 0.349 0.175	ND -0.960 0.480	ND-1.455 0.728	ND-1.745 0.873	ND-4.795 2.398	ND-8.730 4.365	ND-10.470 5.235	ND-28.770 14.385
St.5	Range Mean	ND-0.087 0.044	ND-0.105 0.052	ND-0.288 0.144	ND-0.175 0.087	ND-0.209 0.105	ND-0.575 0.288	ND-8.730 4.365	ND-10.470 5.235	ND-28.770 14.385
St.6	Range Mean	ND-0.029 0.015	ND-0.035 0.017	ND-0.096 0.048	ND-0.058 0.029	ND-0.070 0.035	ND-0.192 0.096	ND-8.730 4.365	ND-10.470 5.235	ND-28.770 14.385

ND*- not detected

Table 6-a2 Chronic daily intake for heavy metals in tap water samples in different stations through dermal absorption pathway from March to December2014 (non-carcinogenic).

Station	Statistics	Pb			Cu			Fe		
		$CDI_{non-carcinogenic}$(μg/kg/d)			$CDI_{non-carcinogenic}$(μg/kg/d)			$CDI_{non-carcinogenic}$(μg/kg/d)		
		Adult men	Adult women	Children	Adult men	Adult women	Children	Adult men	Adult women	Children
St.1	Range	ND*- $0.624*10^{-4}$	ND- $0.760*10^{-4}$	ND- $1.380*10^{-4}$	ND- $1.560*10^{-3}$	ND- $1.900*10^{-3}$	ND- $3.450*10^{-3}$	ND- $56.16*10^{-3}$	ND- $68.40*10^{-3}$	ND- $124.2*10^{-3}$
	Mean	$0.312*10^{-4}$	$0.380*10^{-4}$	$0.690*10^{-4}$	$0.780*10^{-3}$	$0.950*10^{-3}$	$1.725*10^{-3}$	$28.080*10^{-3}$	$34.20*10^{-3}$	$62.10*10^{-3}$
St.2	Range	ND- $1.560*10^{-4}$	ND- $1.900*10^{-4}$	ND- $3.450*10^{-4}$	ND- $8.268*10^{-3}$	ND- $10.07*10^{-3}$	ND- $18.29*10^{-3}$	ND- $59.28*10^{-3}$	ND- $72.20*10^{-3}$	ND- $131.1*10^{-3}$
	Mean	$0.780*10^{-4}$	$0.950*10^{-4}$	$1.725*10^{-4}$	$4.056*10^{-3}$	$4.940*10^{-3}$	$8.970*10^{-3}$	$29.640*10^{-3}$	$36.10*10^{-3}$	$65.550*10^{-3}$
St.3	Range	ND- $0.468*10^{-4}$	ND- $0.570*10^{-4}$	ND- $1.035*10^{-4}$	ND- $1.560*10^{-3}$	ND- $1.900*10^{-3}$	ND- $3.450*10^{-3}$	ND- $46.80*10^{-3}$	ND- $57.00*10^{-3}$	ND- $103.5*10^{-3}$
	Mean	$0.234*10^{-4}$	$0.285*10^{-4}$	$0.518*10^{-4}$	$0.780*10^{-3}$	$0.950*10^{-3}$	$1.725*10^{-3}$	$23.40*10^{-3}$	$28.50*10^{-3}$	$51.750*10^{-3}$
St.4	Range	ND- $1.560*10^{-4}$	ND- $1.900*10^{-4}$	ND- $3.450*10^{-4}$	ND- $7.80*10^{-3}$	ND- $9.50*10^{-3}$	ND- $17.25*10^{-3}$	ND- $46.80*10^{-3}$	ND- $57.00*10^{-3}$	ND- $103.5*10^{-3}$
	Mean	$0.780*10^{-4}$	$0.950*10^{-4}$	$1.725*10^{-4}$	$3.90*10^{-3}$	$4.750*10^{-3}$	$8.625*10^{-3}$	$23.40*10^{-3}$	$28.50*10^{-3}$	$51.750*10^{-3}$
St.5	Range	ND- $0.468*10^{-4}$	ND- $0.570*10^{-4}$	ND- $1.035*10^{-4}$	ND- $0.936*10^{-3}$	ND- $1.140*10^{-3}$	ND- $2.070*10^{-3}$	ND- $46.80*10^{-3}$	ND- $57.00*10^{-3}$	ND- $103.5*10^{-3}$
	Mean	$0.234*10^{-4}$	$0.285*10^{-4}$	$0.518*10^{-4}$	$0.468*10^{-3}$	$0.570*10^{-3}$	$1.035*10^{-3}$	$23.40*10^{-3}$	$28.50*10^{-3}$	$51.750*10^{-3}$
St.6	Range	ND- $0.156*10^{-4}$	ND- $0.190*10^{-4}$	ND- $0.345*10^{-4}$	ND- $0.312*10^{-3}$	ND- $0.380*10^{-3}$	ND- $0.690*10^{-3}$	ND- $46.80*10^{-3}$	ND- $57.00*10^{-3}$	ND- $103.5*10^{-3}$
	Mean	$0.078*10^{-4}$	$0.095*10^{-4}$	$0.173*10^{-4}$	$0.156*10^{-3}$	$0.190*10^{-3}$	$0.345*10^{-3}$	$23.40*10^{-3}$	$28.50*10^{-3}$	$51.750*10^{-3}$

ND*- not detected

Table 6-b Chronic daily intake for heavy metals in tap water samples in six stations through ingestion pathway from March to December2014 (carcinogenic).

Station	Statistics	Pb		
		$CDI_{carcinogenic}$(μ g/kg/d)		
		Adult men	Adult women	Children
St.1	Range	ND-0.050	ND-0.060	ND-0.032
	Mean	0.025	0.030	0.016
St.2	Range	ND-0.125	ND-0.150	ND-0.080
	Mean	0.063	0.075	0.040
St.3	Range	ND-0.038	ND-0.045	ND-0.024
	Mean	0.019	0.023	0.012
St.4	Range	ND-0.125	ND-0.150	ND-0.080
	Mean	0.063	0.075	0.040
St.5	Range	ND-0.038	ND-0.045	ND-0.024
	Mean	0.019	0.023	0.012
St.6	Range	ND-0.013	ND-0.015	ND-0.008
	Mean	0.006	0.008	0.004

The summary of calculated *HQ* values for ingestion and dermal contact of drinking water in six stations are listed in table 7. The order of the non-carcinogenic risk is children>adult women>adult men for all stations. Table 8 explained the total non-carcinogenic risk *HI* in the three age groups of adult men, adult women and children which is less than one. The order of the hazard index for age groups of adult men, adult women and children are Pb>Cu>Fe respectively, the hazard index order for different age groups is: children>adult women>adult men for all stations as shown in figure 2. The values of *HI* for ingestion and dermal contact of drinking water in six stations is less than 1, so the population in Baghdad city is in a safe area according to the concept of *HI* .

Heavy metals carcinogenic risk for consumer can be expressed by CR_{ing}, which are calculated for Pb as listed in table 9. The carcinogenic slope factor SF_{ing} values for copper and iron are not available. The order of the carcinogenic risk through ingestion for lead is adult women>adult men>children as shown in figure 3. The carcinogenic risk for children has smaller value than for adults' men and women because of the shorter interval of exposure for children. For all stations the values of CR_{ing} are between 10^{-6} and 10^{-4}, this means that all stations are within the acceptable level for carcinogenic risk for lead.

Table 7 Hazard quotient for ingestion and dermal contact for heavy metals.

Station	HQ_{ing}			HQ_{derm}		
	Adult men	Adult women	Children	Adult men	Adult women	Children
	Pb					
St.1	0.083	0.098	0.274	$0.149*10^{-3}$	$0.181*10^{-3}$	$0.329*10^{-3}$
St.2	0.208	0.249	0.686	$0.371*10^{-3}$	$0.452*10^{-3}$	$0.821*10^{-3}$
St.3	0.062	0.075	0.206	$0.111*10^{-3}$	$0.136*10^{-3}$	$0.246*10^{-3}$
St.4	0.208	0.249	0.686	$0.371*10^{-3}$	$0.452*10^{-3}$	$0.821*10^{-3}$
St.5	0.062	0.075	0.206	$0.111*10^{-3}$	$0.136*10^{-3}$	$0.246*10^{-3}$
St.6	0.021	0.025	0.069	$0.037*10^{-3}$	$0.045*10^{-3}$	$0.082*10^{-3}$
	Cu					
St.1	0.0073	0.0087	0.0240	$0.195*10^{-3}$	$0.238*10^{-3}$	$0.431*10^{-3}$
St.2	0.0386	0.0463	0.1271	$1.034*10^{-3}$	$1.259*10^{-3}$	$2.286*10^{-3}$
St.3	0.0073	0.0087	0.0240	$0.195*10^{-3}$	$0.238*10^{-3}$	$0.431*10^{-3}$
St.4	0.0364	0.0436	0.1199	$0.975*10^{-3}$	$1.186*10^{-3}$	$2.156*10^{-3}$
St.5	0.0044	0.0052	0.0144	$0.117*10^{-3}$	$0.143*10^{-3}$	$0.259*10^{-3}$
St.6	0.0015	0.0018	0.0048	$0.039*10^{-3}$	$0.048*10^{-3}$	$0.086*10^{-3}$
	Fe					
St.1	0.015	0.018	0.049	$0.401*10^{-3}$	$0.489*10^{-3}$	$0.887*10^{-3}$
St.2	0.016	0.019	0.052	$0.423*10^{-3}$	$0.516*10^{-3}$	$0.936*10^{-3}$
St.3	0.012	0.015	0.041	$0.334*10^{-3}$	$0.407*10^{-3}$	$0.739*10^{-3}$
St.4	0.012	0.015	0.041	$0.334*10^{-3}$	$0.407*10^{-3}$	$0.739*10^{-3}$
St.5	0.012	0.015	0.041	$0.334*10^{-3}$	$0.407*10^{-3}$	$0.739*10^{-3}$
St.6	0.012	0.015	0.041	$0.334*10^{-3}$	$0.407*10^{-3}$	$0.739*10^{-3}$

Table 8 Hazard index by ingestion and dermal contact (non-carcinogenic).

Station	HI								
	Pb			Cu			Fe		
	Adult men	Adult women	Children	Adult men	Adult women	Children	Adult men	Adult women	Children
St.1	0.0831	0.0982	0.2743	0.0075	0.0089	0.0244	0.0154	0.0185	0.0499
St.2	0.2084	0.2495	0.6878	0.0396	0.0475	0.1294	0.0164	0.0195	0.0529
St.3	0.0621	0.0751	0.2062	0.0075	0.0089	0.0244	0.0123	0.0154	0.0417
St.4	0.2084	0.2495	0.6878	0.0374	0.0448	0.1221	0.0123	0.0154	0.0417
St.5	0.0621	0.0751	0.2062	0.0045	0.0053	0.0147	0.0123	0.0154	0.0417
St.6	0.0210	0.0250	0.0691	0.0015	0.0018	0.0049	0.0123	0.0154	0.0417

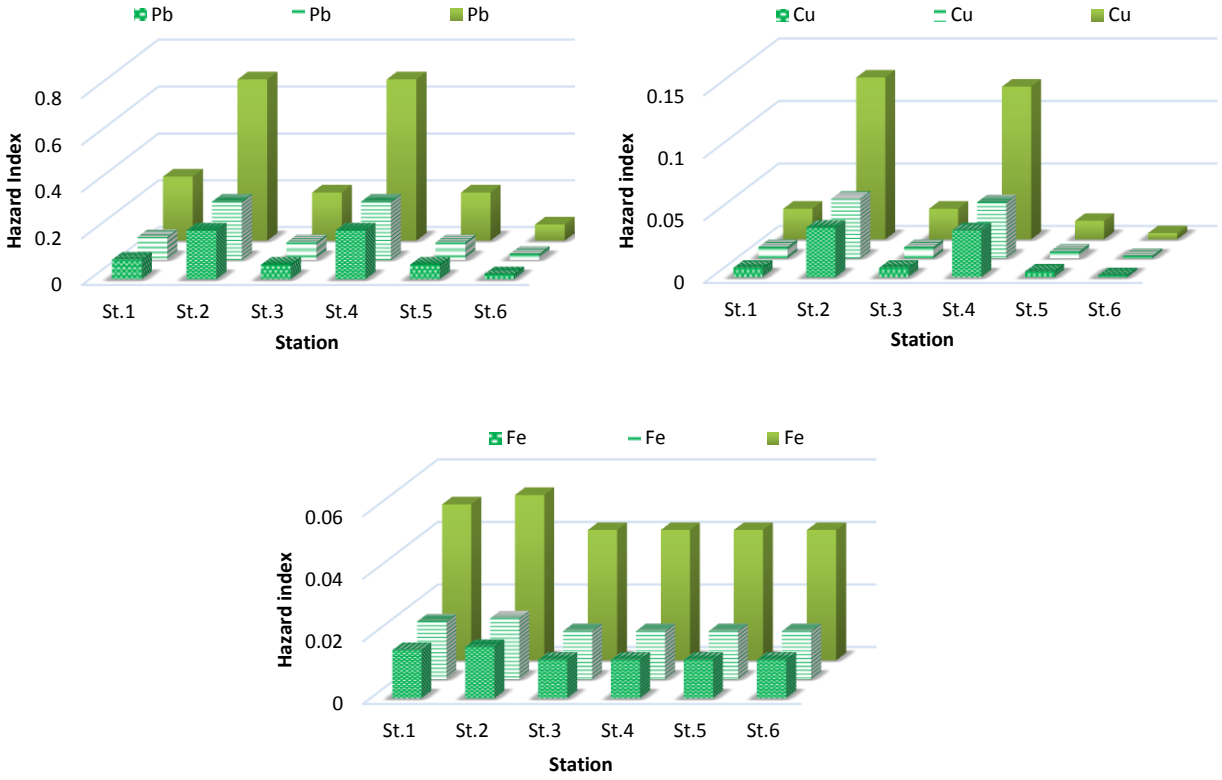

Figure 2 Hazard index for Pb, Cu and Fe in six stations.

Table 9 Carcinogenic risk by ingestion for lead.

Sta.	CR_{ing}		
	Adult men	Adult women	Children
St.1	$0.425*10^{-6}$	$0.510*10^{-6}$	$0.272*10^{-6}$
St.2	$1.063*10^{-6}$	$1.275*10^{-6}$	$0.680*10^{-6}$
St.3	$0.323*10^{-6}$	$0.383*10^{-6}$	$0.204*10^{-6}$
St.4	$1.063*10^{-6}$	$1.275*10^{-6}$	$0.680*10^{-6}$
St.5	$0.323*10^{-6}$	$0.383*10^{-6}$	$0.204*10^{-6}$
St.6	$0.111*10^{-6}$	$0.128*10^{-6}$	$0.068*10^{-6}$

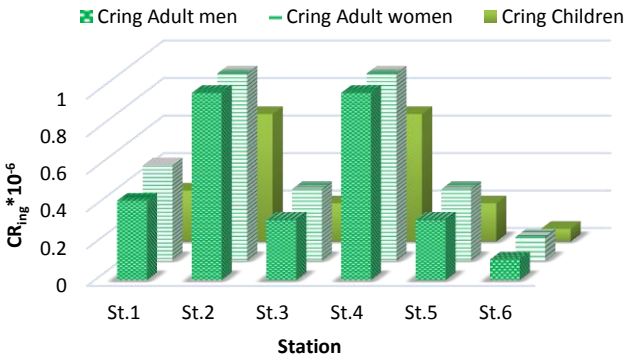

Figure 3 Carcinogenic risk via ingestion for lead.

Conclusion

As a conclusion of this study is that the indices of non-carcinogenic for two exposure pathways, HQ_{ing} and HQ_{derm} for the three heavy metals are under the permissible limit (unity) in all stations. Hazard index for all station is also under unity. Carcinogenic risk for lead in all stations is within the acceptable limit. This study suggests that more care must be given for test heavy metals concentrations in all drinking water treatment plants. By using the initial information of this study analysis of heavy metals, the planning and monitoring of future drinking water quality in Baghdad city is available. Also help government to provide ways to minimize the exposure at optimum levels. More studies must be done by experts in order to protect the weakness classes (children) in society from the harmful effect of heavy metals in air, water and soil.

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