International Journal of Applied Chemistry.
ISSN 0973-1792 Volume 15, Number 1 (2019) pp. 15-19

http://www.ripublication.com

Health risk assessment of dissolved heavy metals in some selected water samples: Dakahlia, Egypt

A. El Sayed El Wasif [a] , Sh. M. El Dafrawy* [b]
S. M. Nour El Din Moalla [c] , and M. M. El Defrawy [b]

[a)] Water & Waste water Company in Dakahlia,
[b)] Faculty of Science, Mansoura University
[c)] Faculty of Science, Port Saied University

Abstract

The investigation of heavy metals concentrations of Cd, Cu, Cr, Ni, Fe, Pb and Zn were done in some drinking water samples collected from Dkrns sector, Dakahlia governorate, Egypt. The heavy metals potential health risks were studied for the local inhabitants. The Atomic Absorption Spectrophotometer (AAS) was used for the determination of heavy metal concentrations that compared with permissible limits set by US Environmental Protection Agency (US EPA) and World Health Organization (WHO). The Cd concentrations exceed the respective permissible limits in dry seasons, while Cu, Cr, Fe and Zn concentrations were observed within their respective limits. Moreover, Ni and Pb concentrations were UDL. The parameters of health risk such as chronic daily intake (CDI), hazard quotient (HQ) and hazard index (HI) were studied. HQs and HIs of selected heavy metals were recorded in the order of Cd > Cr > Cu > Fe > Zn. HIs <1 for heavy metals in the collected drinking water samples. Therefore no health risk to the local inhabitants except in dry seasons HQ and HI >1 were observed due to Cd. Furthermore, multivariate statistical analysis such as one-way analysis of variance (ANOVA) and inter-metal correlation matrix were done.

Keywords: daily intake; drinking water; surface water; heavy metals; health risk assessment.

INTRODUCTION

One of a vital substance in the universe is water. So, attention has raised on heavy metal ions concentrations that are contaminated in drinking water and became a worldwide health concern[1].

Heavy metals are a major concern as reported in epidemiological research in recent years of the risk of human exposure to heavy metals due to their non-biodegradable nature [2] [3] [4] [5]. It is identified that malnutrition and diseases such as immune dysfunction, abdominal pain, anorexia, shortness of breath, cardiovascular diseases, kidney and liver-related disorders. In addition, various types of cancer could be caused by supplement inadequacy, as well as by excessive intake of heavy metals in contaminated food and drinking water [2] [6] [7] [8] [9] [10].

The heavy metals species causes antagonistic impacts on human involve toxicity, neurotoxicity, carcinogenicity, teratogenicity and mutagenic effects [11] [12].

A cumulative poisons metals in the body such as Cadmium, Chromium, Nickel, Lead and Mercury which cause environmental hazards and are causing serious diseases [13] [14] [15] [16] [17] [18]. While, essential metals for humans such as Copper, Manganese, Iron and Zinc are important in a biological systems function, but they can cause adverse toxic effects when their ingestion is excessively elevated [19].

Therefore, in this study, it is important to assess the heavy metals concentrations of Cd, Cu, Cr, Ni, Fe, Pb and Zn in collected drinking water, possible sources of contamination, and their respective potential health risks on populations in Dkrns sector– Dakahlia governorate, Egypt. While it was found that the seriousness of drinking water contamination with heavy metals was not studied before for that area.

Health risk assessment model recommended by the United States Environmental Protection Agency (US EPA) has been widely used to assess the potential health risks induced by the metals in various environments. Different univariate and multivariate statistical analyses were used to study heavy metal relevancy, for example, one-way analysis of variance (ANOVA) and inter-metals correlation [20].

These methodologies have been already used worldwide in several researches to investigate the adverse effects of contaminated water on human health [2] [6] [21] [22] [23] [24] [25] [26] [27] [28] [29].

1 MATERIALS AND METHODS

1.1 Study area

Dkrns sector is an administrative district in Dakahlia governorate, northern Egypt (Fig. 1). It is situated about 20 km east of Mansoura, the capital of Dakahlia. It includes three areas (Dkrns, Menyat El Nasr and Bani Ebeid). Geographically, the sector lays out at 31° 5′ 18″ North latitude, 31° 35′ 49″ East latitude, with a total population is more than 0.8 million [30] and the area of 43283 km^2.

Fig.1: Location of Dkrns sector in Egypt.

The daily average temperature ranges from 12.5 °C in January to 26.6 °C in August [31]. Where, there are two main branches of a river in Dkrns sector “Al-Bahr El-Sagher & Bahr Tanah” which they are the main sources of drinking water for the local population in the sector (Fig. 2). As these two branches of the river are the end of the downstream of the main river so that the potential for contaminants is expected to be high.

Along “Al-Bahr El-Sagher” branch of a river there are many compact units used for the treatment of surface water. We have chosen the first upstream unit located in the sector Meet Dafer (Location 1, Fig. 2) and the last downstream one Berembal El-Qadima (Location 2, Fig. 2) for samples collection. While, on “Bahr Tanah” branch there is the main plant Meet Faris water treatment plant (Location 3, Fig. 2).

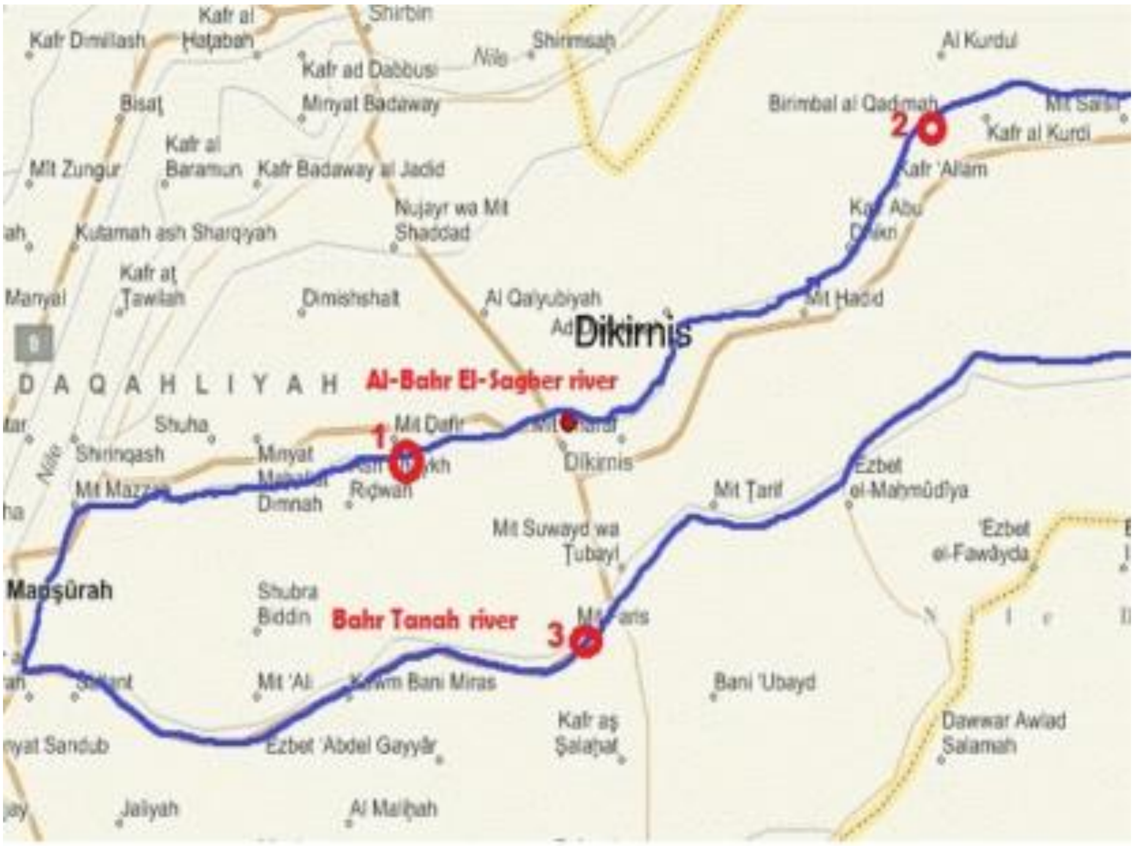

Fig. 2: Locations of water samples collection in Dkrns sector.

1.2 Water sampling

Collection of drinking water samples done from three locations in Dkrns sector from November 2015 to October 2016 [32].

<u>Location (1):</u> "Meet Dafer" compact unit on upstream of "Al-Bahr El-Sagher" branch of a river (Fig. 2).

<u>Location (2):</u> "Berembal El Qadima" compact unit on downstream of "Al-Bahr El Sagher" branch of a river (Fig. 2).

<u>Location (3):</u> "Meet Faris" water treatment plant. On "Bahr Tanah" branch of a river (Fig. 2).

From each location, two samples were collected monthly from treated water "drinking water" in ½ L glass bottle and acidified by 2 ml HNO_3 [33]. Then stored at 4 °C until transported to the Atomic Absorption laboratory in Faculty of Science Mansoura University for analysis.

1.3 Chemical analysis procedures

Analysis procedures were carried out as adopted in the standard methods for the examination of water and wastewater (APHA, 2005), by using atomic spectrophotometer model "Sens AA Dual" made in Australia. The results were compared with the maximum permissible limit (MPL) according to World Health Organization (WHO, 2008) for Drinking Water.

On the other hand, atomic absorption spectrometer (AAS) technique is used for analysis of metals worldwide. In this issue, AAS produces high selectivity, which is due to the use of selective irradiation source. Moreover, the "Sens AA Dual" AAS can detect elements as shown in (Table 1).

Table 1 :characters of atomic spectrophotometer model "Sens AA Dual"

Element	lamp current (mA)	wave length (nm)	slit width (nm)
Cu	3.00	324.70	0.50
Fe	7.00	248.30	0.20
Zn	5.00	213.90	0.50
Ni	5.00	232	0.20
Pb	5.00	217	1.00
Cr	6.00	357.90	0.20
Cd	3.00	228.80	0.50

1.4 Approaches for assessing health risks

Risk assessment of metals is carried out according to exposure pathways of contaminants recommended by (US EPA) [34][35]. The potential exposure pathways of the metals including Direct ingestion of drinking water and dermal absorption of contaminants in water adhered to exposed skin [36].

Where, in this study, the concern was focused on oral intake. According to the EPA, residential ingestion exposure of metals in drinking water can calculate by Eq. (1) [37].

$$\textbf{Chronic Daily Intake CDI } (\mu g/kg\text{-}day) = \frac{C_W \cdot IR \cdot EF \cdot ED}{BW \cdot AT} \qquad \textbf{Eq. (1)}$$

According to EPA; C_W: Concentration of the metal in water "measured value of sample" (µg/L). The other parameters used IR: Ingestion Rate (Liters/day), EF: Exposure Frequency "daily" (days/year), ED: Exposure Duration (years), BW: Body Weight (kg), AT: pathway specific period of exposure "i.e., ED x 365 days/year" (day) are 2, 365, 70, 70 and 25550 respectively.

Hazard Quotient (HQ) can calculate to estimate the risk by Eq. (2)

$$\textbf{Hazard Quotient (HQ)} = \frac{CDI}{R_fD} \qquad \textbf{Eq. (2)}$$

According to EPA; CDI: Intake Dose (µg/kg-day). R_fD: Reference Dose (µg/kg-day). Where R_fD is the oral reference dose or tolerable daily intake which was obtained from the (US EPA) table [35] [38]. And refers to the maximum amount of toxicant which does not translate to an adverse effect on the one ingesting the toxicants. The parameters used in the calculation for Cd, Cu, Cr, Ni, Fe, Pb and Zn in (µg/kg-day) are 0.5, 37, 1500, 20, 700, 36 and 300 respectively.

Hazard Index (HI) can calculate to assess the overall risk by all metals in one sample and also, the sum of individual Hazard Quotient (HQ) of each metal by Eq.(3) [37].

$$\textbf{Hazard Index (HI)} = \sum_{i=1}^{n} HQ_i \qquad \textbf{Eq. (3)}$$

HQ or HI < 1 indicates no significant health risks; a value ≥1 indicates significant health risks, which increase with increasing value of HQ or HI.

1.5 Statistical analysis

Microsoft Excel 2010 was used in statistical analysis of the experimental data and the values were expressed as the mean ±SD. The location maps of the study area were obtained from Google Map.

2 RESULTS AND DISCUSSION

2.1 Drinking water contamination

(Table 2) summarizes the concentrations (µg/L) of selected heavy metals in drinking water collected from the area focused in the three sampling locations

(Location 1 "Meet Dafer", Location 2 "Berembal EL_Qadima" and Location 3 "Meet Faris").

Table 2 : concentrations (µg/L) of selected heavy metals in drinking water samples

Parameter			Cd	Cu	Cr	Ni	Fe	Pb	Zn
Permissible limits(WHO) [a]			3	2000	50	70	300	10	3000
Loc. 1 (n[b] =24) Meet Dafer	Statistics	MIN	UDL[c]	UDL	UDL	UDL	UDL	UDL	UDL
		MAX	19.00	194.00	14.00	UDL	188.00	UDL	8.00
		MEAN	2.00	29.00	4.83	UDL	47.17	UDL	0.63
		SD	± 5.30[d]	± 51.76	± 4.51	UDL	± 53.69	UDL	± 2.12
Loc. 2 (n=24) Berembal EL_Qadima	Statistics	MIN	UDL	UDL	UDL	UDL	UDL	UDL	UDL
		MAX	23.00	195.00	22.00	UDL	244.00	UDL	13.00
		MEAN	3.42	32.75	8.54	UDL	59.21	UDL	2.21
		SD	± 5.96	± 52.52	± 6.45	UDL	± 66.73	UDL	± 3.83
Loc. 3 (n=24) Meet Faris	Statistics	MIN	UDL	UDL	UDL	UDL	1.00	UDL	UDL
		MAX	5.00	153.00	20.00	UDL	108.00	UDL	1.00
		MEAN	1.13	27.38	5.08	UDL	34.58	UDL	0.08
		SD	± 1.45	± 42.63	± 7.09	UDL	± 30.26	UDL	± 0.28

[a] World Health Organization (WHO, 2008); [b] Number of water samples; [c] Under Detection Limits; [d] Standard Deviation.

The concentrations of selected metals in drinking water collected samples were found in the order of Fe > Cu > Cr > Cd > Zn > Ni and Pb respectively, in the three locations of the

study area. The Cd concentrations are higher than their respective permissible limits in all samples that taken in February 2016 (the dry season). However, the concentrations of Cu, Cr, Ni, Fe, Pb and Zn were observed within their respective permissible limits set by WHO (2008) in all samples (Table 2). The Cd mean concentrations in drinking water samples from Meet Dafer, Berembal EL_Qadima and Meet Faris were (2.00 ± 5.30), (3.42 ± 5.96) and (1.13 ± 1.45) µg/L, respectively (Table 2). (23.00 µg/L) was the highest Cd concentration noted in 25% of the investigated water samples. The regard of high concentration of Cd might be caused by agricultural and industrial contaminations, where usage of phosphate fertilizers in agriculture at the same time of the lowest level of Nile water at this time of the year (dry season) might increase the concentration of Cd, as well as runoff from waste batteries and paints.
The Cu mean concentrations in drinking water samples were (29.00 ± 51.76), (32.75 ± 52.52) and (27.38 ± 42.63) µg/L in the three locations, respectively (Table 2). The Cr mean concentrations in drinking water samples in the same three locations were (4.83 ± 4.51), (8.54 ± 6.45) and (5.08 ± 7.09) µg/L, respectively (Table 2). The Fe mean concentrations in drinking water samples in the same three locations were (47.17 ± 53.69), (59.21 ± 66.73) and (34.58 ± 30.26) µg/L, respectively (Table 2).

The Zn mean concentrations in drinking water samples in the same three locations were (0.63 ± 2.12), (2.21 ± 3.83) and (0.08 ± 0.28) µg/L, respectively (Table 2). Ni and Pb concentrations in all collected water samples were (UDL).

Based on the above discussed results, It could be accomplished that heavy metals such as Fe, Cu, Cr, Cd and Zn displayed increasing contamination in the study area from upstream "Meet Dafer" to downstream "Berembal El-Qadima". This might be caused by agricultural and industrial contamination along “Al-Bahr El-Sagher” branch of the river.

2.2 Health risk assessments

2.2.1 Chronic daily intake of metals

(Table 3) outlines Chronic daily Intake (CDIs, µg/(kg·day)) of heavy metals through drinking water. The heavy metals CDIs were recorded in the order of Fe > Cu > Cr > Cd > Zn through surface water consumptions. Moreover, the Cd CDIs exceeded the respective R_fD value in February 2016 (the dry season) in Meet Dafer and Berembal EL_Qadima, while that of Cu, Cr, Fe and Zn were within their respective limit of R_fD set by US EPA.

Table 3 : Chronic daily Intake (CDIs, µg/(kg·day)) of heavy metals through drinking water consumption

Parameter	Cd	Cu	Cr	Ni	Fe	Pb	Zn
Meet Dafer (n [a] =24)	0.06 ± 0.15	0.83 ± 1.48	0.14 ± 0.13	NC [b]	1.35 ± 1.53	NC	0.02 ± 0.06
Berembal EL_Qadima (n=24)	0.10 ± 0.17	0.94 ± 1.50	0.24 ± 0.18	NC	1.69 ± 1.91	NC	0.06 ± 0.11
Meet Faris (n=24)	0.03 ± 0.04	0.78 ± 1.22	0.15 ± 0.20	NC	0.99 ± 0.86	NC	0.002 ± 0.01

[a] Number of water samples; [b] not calculated; ± Standard Deviation.

The range of Cd mean CDIs µg/(kg·day) was from (0.03 to 0.10) through consumption of drinking water in the selected three locations "Meet Dafer", "Berembal EL_Qadima" and "Meet Faris" (Table 3). The lowest Cd CDI observed µg/(kg·day) at Meet Faris was (0.03), while the highest Cd CDI observed μg/(kg·day) at Berembal EL_Qadima was (0.10) through consumption of drinking water. The range of Cu mean CDIs μg/(kg·day) was from (0.78 to 0.94) through consumption of drinking water in the same three locations. The lowest Cu CDI observed μg/(kg·day) at Meet Faris was (0.78), while the highest Cu CDI observed μg/(kg·day) at Berembal EL_Qadima was (0.94) through consumption of drinking water (Table 3).

The range of Cr mean CDIs μg/(kg·day) was from (0.14 to 0.24) through consumption of drinking water in the same three locations. The lowest Cr CDI observed μg/(kg·day) at Meet Dafer was (0.14), while the highest Cr CDI observed μg/(kg·day) at Berembal EL_Qadima was (0.24) through consumption of drinking water (Table 3). The range of Fe mean CDIs μg/(kg·day) was from (0.99 to 1.69) through consumption of drinking water in the same three locations.

The lowest Fe CDI observed μg/(kg·day) at Meet Faris was (0.99), while the highest Fe CDI observed μg/(kg·day) at Berembal EL_Qadima was (1.69) through consumption of drinking water (Table 3). The range of Zn mean CDIs μg/(kg·day) was from (0.002 to 0.06) in the same three locations through consumption of drinking water. The lowest Zn CDI observed μg/(kg·day) at Meet Faris was (0.002), while the highest Zn CDI observed μg/(kg·day) at Berembal EL_Qadima was (0.06) through consumption of drinking water (Table 3). The mean Ni and Pb CDIs were not calculated through consumption of drinking water because their concentrations in collected samples were UDL.

2.2.2 Hazard Quotient (HQ) & Hazard Indexes (HI) of metals

Hazard quotient (HQ) approach was used for assessment of health risks to local residents in the focused area through the consumption of drinking water. The value of HQ >1 indicates that potential health risk may exist.

(Table 4) outlines the heavy metals' HQ values. According to the drinking water quality in the focused area, the HQs of selected heavy metals were found in the order of Cd > Cr > Cu > Fe > Zn through surface water consumptions. In Meet Dafer, the mean HQ index values for Cd, Cu, Cr, Fe and Zn were 0.11, 0.02, 0.05, 0.002 and 0.0001, respectively for drinking water (Table 4).

Table 4 : Hazard Quotient (HQs) of heavy metals through drinking water consumption

Parameter	Statistics	Cd	Cu	Cr	Ni	Fe	Pb	Zn
Permissible limits (USEPA) [a]		1	1	1	1	1	1	1
Loc. 1 (n^b =24) Meet Dafer	Range	0.00 - 1.09	0.00 - 0.15	0.00 - 0.13	NC [d]	0.00 - 0.01	NC	0.00 - 0.001
	MEAN	0.11	0.02	0.05		0.002		0.0001
	SD [c]	± 0.303	± 0.040	± 0.043		± 0.002		± 0.0002
Loc. 2 (n=24) Berembal EL_Qadima	Range	0.00 - 1.31	0.00 - 0.15	0.00 - 0.21	NC	0.00 - 0.01	NC	0.00 - 0.0012
	MEAN	0.20	0.03	0.08		0.002		0.0002
	SD	± 0.341	± 0.041	± 0.061		± 0.003		± 0.0004
Loc. 3 (n=24) Meet Faris	Range	0.00 - 0.29	0.00 - 0.12	0.00 - 0.19	NC	0.00 - 0.01	NC	0.00 - 0.0001
	MEAN	0.06	0.02	0.05		0.001		0.00001
	SD	± 0.083	± 0.033	± 0.068		± 0.001		± 0.00003

[a] US Environmental Protection Agency; [b] Number of water samples; [c] Standard Deviation; [d] Not calculated.

In Berembal EL_Qadima, the mean HQ index values for Cd, Cu, Cr, Fe and Zn were 0.2, 0.03, 0.08, 0.002 and 0.0002 respectively for drinking water (Table 4). Similarly, in Meet Faris, the mean HQ index values for Cd, Cu, Cr, Fe and Zn were 0.06, 0.02, 0.05, 0.001 and 0.00003, respectively for drinking water (Table 4). However, the mean HQs of Ni and Pb through the consumption of drinking water were not calculated because their concentrations in collected water samples were UDL. Moreover, the Cd HQs exceeded the respective limit value (1.09 and 1.31) in Meet Dafer and Berembal EL_Qadima respectively in February 2016 (the dry season) which showed that the local populations around that areas are exposing to a high potential health risk, while that of Cu, Cr, Fe and Zn were within their respective HQs limit set by US EPA.

Hazard index (HI) approach was used for assessment of overall potential health risk posed by more than one heavy metal. The hazard index (HI) is the sum of all hazard quotients (HQs) calculated for individual heavy metal. A value of $HI < 1$ indicates no significant risks; a value ≥ 1 indicates significant risks, which increase with increasing value of HI. It assumes that the magnitude of the adverse effect will be proportional to the sum of multiple metal exposures. It also assumes similar working mechanisms that linearly affect the target organ.

Among selected metals, Cd contributed the most to the HI total value (5.26) in February 2016 (the dry season) (Fig. 3), suggesting that this metal may possibly be associated with serious health concern through drinking water consumption.

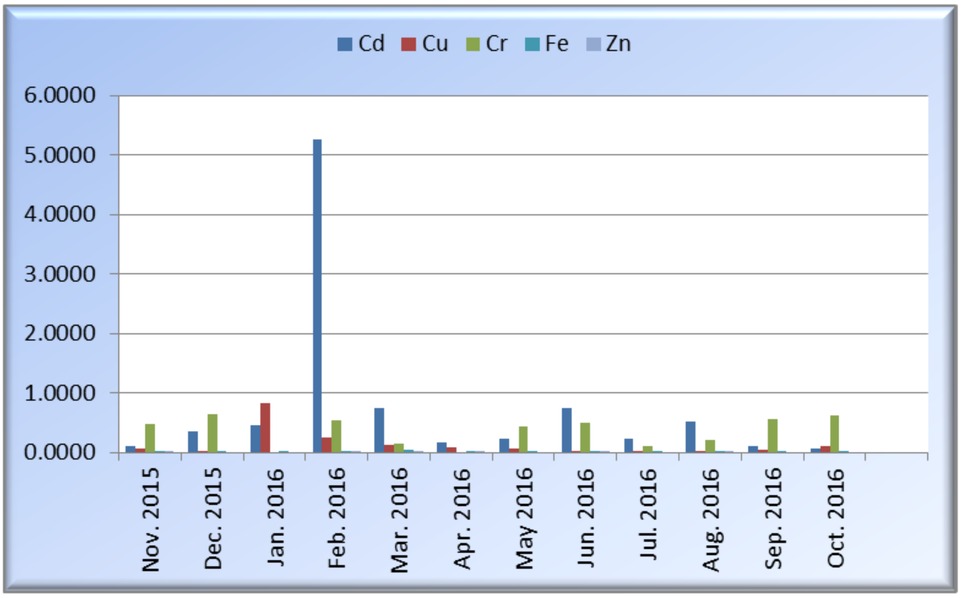

Fig. 3: Hazard Index (HI) of Metals

However, the values of HI of other heavy metals were less than unity, demonstrating that no hazard to residents through surface water consumption. Since more than one toxicant is present, the interactions are considered.

The hazard indexes (HIs) of each sample are summarized in (Fig. 4). The HI of sample 1 and sample 2 which taken from Meet Dafer were 1.20 and 1.21in February 2016 (Fig. 4). The HI of sample 3and sample 4 which taken from Berembal EL_Qadima were 1.45 and 1.50 in February 2016 (Fig. 4), suggesting that this area from upstream to downstream along “Al-Bahr El-Sagher” branch of the river showed highly health risk during the dry season. However, the values of HI of other samples were within their respective limits.

The existing results show that Cd was the major component contributing to the potential health risk. From the study data, it is clear that Cd poses a high potential risk for local populations from Meet Dafer to Berembal EL_Qadima through the consumption of water from “Al-Bahr El-Sagher” branch of the river during dry seasons. Therefore, some effective experimental procedure might be necessary to remediate contaminated drinking water in study area, and their implications for human health should be identified urgently by in-depth studies, especially since it is common for the potential health adverse effects of long-term exposure to higher concentration of Cd may cause kidney damage as well as producing acute health effects [39]. Moreover, accumulation of Cd in human body leads to certain disorder including cardiovascular diseases, liver and nervous system [40]. Another study reports that the dietary intake of Cd can increase the risk of postmenopausal breast cancer [41].

The HI of Ni and Pb through the consumption of drinking water were not calculated because their concentrations in collected water samples were UDL.

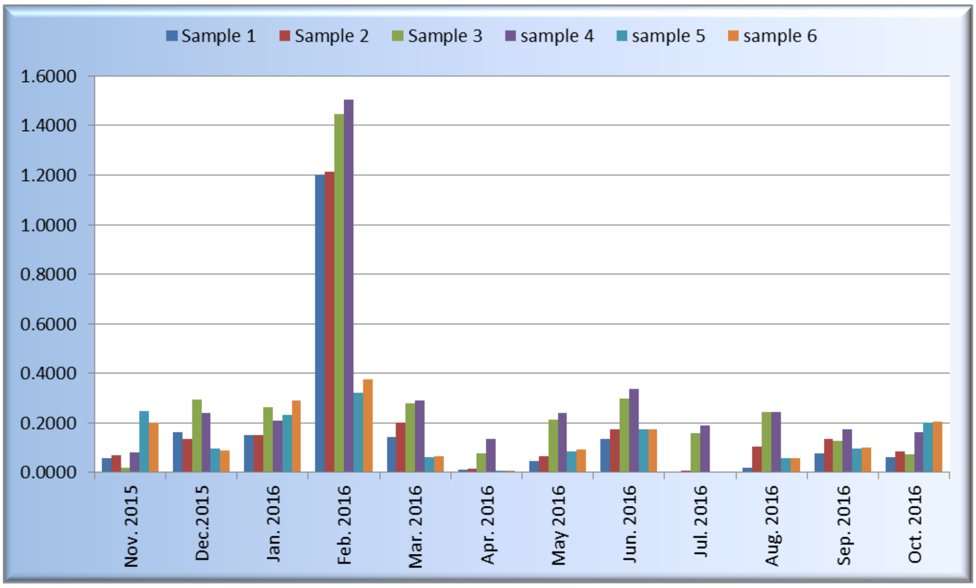

Fig. 4: Hazard Index (HI) of Samples

2.3 Statistical analysis

2.3.1 One-way ANOVA comparison

(Table 5) outlines the statistical comparison of heavy metal contaminations in different drinking water sampling locations, using one-way ANOVA analysis. It displays no significant statistical difference (P =0.28), which indicates that different locations were not contributing to the mean concentrations of metal in the collected water samples (Table 5).

Table 5 : One-way ANOVA comparison of selected heavy metals in the study area

Source of Variation	SS [a]	Df [b]	MS [c]	F [d]	*P*-value	F crit
Between Groups	0.0035	2	0.002	1.28	0.28	3.02
Within Groups	0.4848	357	0.001			
Total	0.4883	359				

a Sum of squares; b Degree of freedom; c Mean square; d Factor.

However, it is observed that a different variation value for every heavy metal for an individual location in the study area (Fig. 5).

The concentrations of Zn were the significant statistical difference (P=0.01) in the collected drinking water samples from Berembal EL_Qadima as compared to those from Meet Faris drinking water samples (Table 6) & Fig. 5(e). However, no significant variation was found for Cd, Cu, Cr and Fe in collected drinking water samples from several locations (Table 6) & Fig. 5(a,b,c,d). The variations of Ni and Pb through the consumption of drinking water of collected samples were not calculated because of their concentrations UDL.

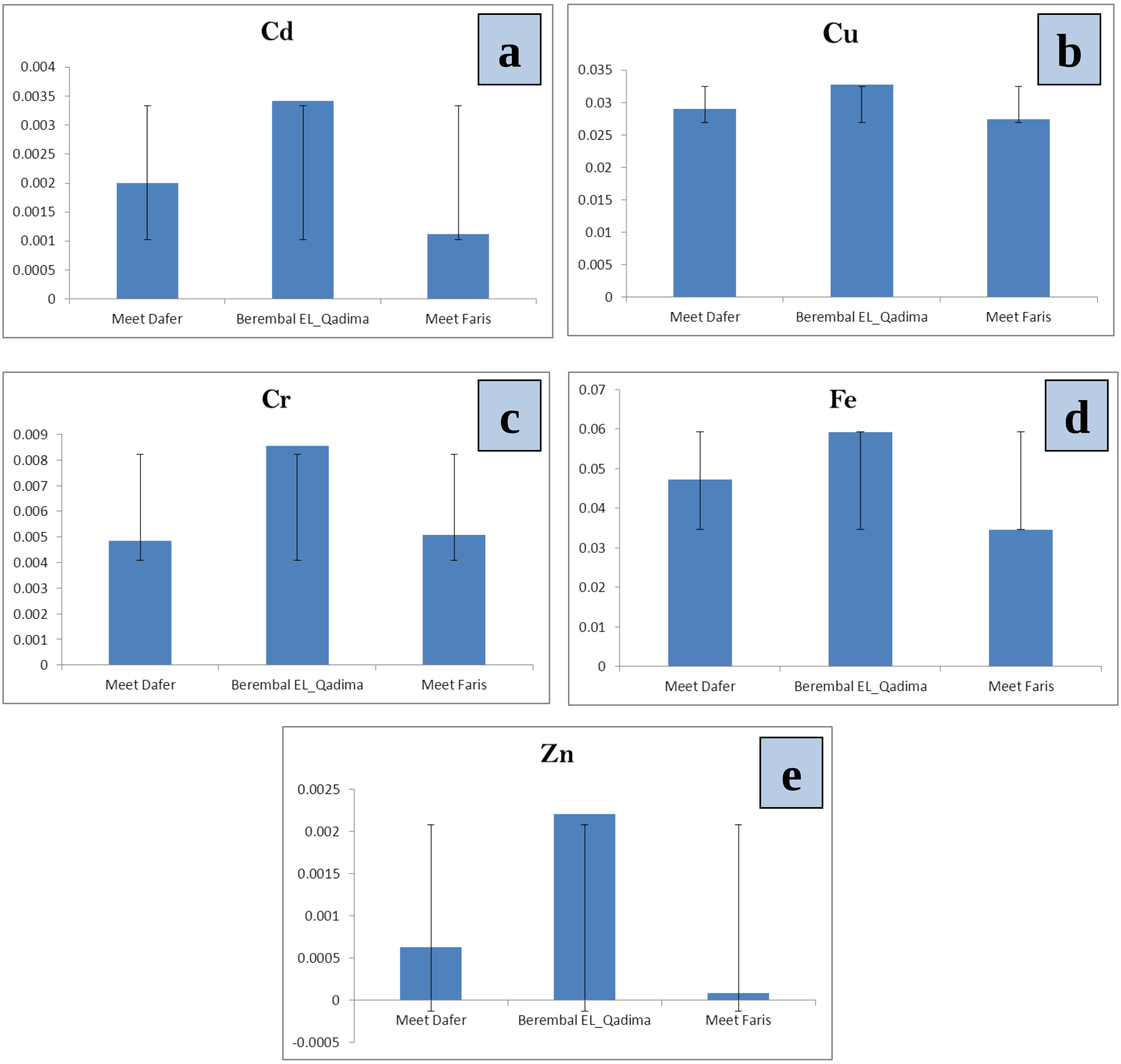

Fig. 5: One-way ANOVA boxplots comparison for Cd (a), Cu (b), Cr (c), Fe (d) and Zn (e)

Table 6 : One-way ANOVA comparison of selected heavy metals for different locations in the study area

Metals	Source of Variation	SS [a]	df [b]	MS [c]	F [d]	*P*-value	F crit
Cd	Between Groups	6.4E-05	2	3.2E-05	1.46	0.24	3.13
	Within Groups	0.00151	69	2.2E-05			
	Total	0.00158	71				
Cu	Between Groups	0.00036	2	0.0002	0.08	0.93	3.13
	Within Groups	0.16686	69	0.0024			
	Total	0.16723	71				
Cr	Between Groups	0.00021	2	0.0001	2.76	0.07	3.13
	Within Groups	0.00258	69	3.7E-05			
	Total	0.00279	71				
Fe	Between Groups	0.00728	2	0.0036	1.32	0.27	3.13
	Within Groups	0.18977	69	0.0028			
	Total	0.19705	71				
Zn	Between Groups	5.9E-05	2	2.9E-05	4.55	0.01	3.13
	Within Groups	0.00044	69	6.4E-06			
	Total	0.0005	71				

[a] Sum of squares; [b] Degree of freedom; [c] Mean square; [d] Factor.

2.3.2 Inter-metal correlation

Analysis of inter-metal correlation gives important information about the concentrations of heavy metal and their particular pathways [6] [42] [43] [44]. (Table 7) outlines the heavy metals' inter-metal correlation of collected drinking water samples. As it is evident in the collected drinking water samples, the correlation analysis displayed in some heavy metal pairs positive correlations such as Cd-Zn (r = 0.553). However, there was no correlation for Ni and Pb because their concentrations in collected water samples were UDL. Interestingly, a negative correlation for Cu-Cr pair (r = –0.257) was noted.

Table 7 : Correlation matrix of selected heavy metals in the drinking water (n[a] = 72)

Parameters	*Cd*	*Cu*	*Cr*	*Ni*	*Fe*	*Pb*	*Zn*
Cd	1						
Cu	0.1184	1					
Cr	0.2242	-0.2569	1				
Ni	NC[b]	NC	NC	NC			
Fe	0.1489	-0.0776	0.13	NC	1		
Pb	NC	NC	NC	NC	NC	NC	
Zn	0.5535	0.0317	0.1288	NC	0.0495	NC	1

[a] Number of water samples; [b] not calculated.

3. CONCLUSIONS

The concentrations of heavy metals were the highest for Fe > Cu > Cr > Cd > Zn > Ni and Pb respectively in the collected samples of drinking water. Cd concentrations exceed the quality standards for drinking water (Table 8), while the concentrations of Fe, Cu, Cr, Zn, Ni and Pb were within their permissible limits.

Table 8 : Permissible limits of heavy metal concentrations (mg/l) in drinking water for different international agencies

Agency	Quality parameter						
	Cd	Cu	Cr	Ni	Fe	Pb	Zn
US EPA	0.005	1	0.1	0.1	0.3	0.015	5
WHO	0.003	2	0.05	0.07	0.3	0.01	3
EU	0.005	2	0.05	0.02	0.2	0.01	-

The statistical ANOVA analysis indicated that most of the heavy metal contaminations at study area not significant varied (P >0.05). Moreover, the inter-metal correlation matrix of selected metals in drinking water displayed a positive correlation in heavy metal pairs Cd-Zn.

Based on health risk assessment model, no health risk was observed at different locations (HI < 1) in the study area according to US EPA standards during the period (November 2015 to October 2016) except in February 2016, while Cd was the major element posed potential health risks through the consumption of drinking water to the local populations from “Al-Bahr El-Sagher” branch of the river during the dry seasons. In this way, it is highly recommended that during a dry season, contaminated drinking water in study area should not be used without appropriate treatment.

In addition, to provide a fuller picture to estimate the aggravation human health risk of all pollutants covering this region, the further investigation of heavy metals is highly recommended. And, the contributions of the pollutants from the consumption of local crops that use water from “Al-Bahr El-Sagher” & "Bahr Tanah" branches of a river in agriculture propose as an additional exposure pathway in-depth research in the future.

4. RECOMMENDATIONS

One of the main causes of human health problems is water pollution. Which causes diseases for more than 2.3 billion people worldwide (UNESCO, 2003). (WHO and UNISEF, 2000) recorded more than 2.2 million people die in developing countries every year because of contaminated water consumption and inappropriate sanitation.
The following general recommendations are suggested which may control or facing water quality problems:

- There should be used an appropriate method to eliminate the high concentration of heavy metals in drinking water, especially in the dry season where the concentration of that metals were exceeded permissible limits (e.g.: active carbon method).
- There should be prevented the agricultural drains (sources of contaminants) from flow into drinking water sources.
- There should be continuously replacement and renewal in the distribution network of water for all old and rusted pipelines.
- There should be adequate separations between the pipelines of drinking water and sewage to keep away from sources of contamination.
- There should change an irregular water supply to permanent supply system to keep away from contamination diffusion caused by irregular water supply.
- There should be imposed all industries to adjust sanitation treatment measures and strictly monitored Industrial wastewater disposal.
- There should be kept carefully on the quality of drinking water by enact and strictly apply laws without compromise.
- There should raise the awareness by all ways about the importance of safe drinking water to the population.
- There should be adapting guidance on safety measures and precautions necessary to use the water of the domestic reservoir.
- There should be informed the farmers well about the optimum use of fertilizers and rationalization of usage to minimize the risk of the contribution of agricultural practices to water contamination.
- Further studies of heavy metal contaminations are recommended. In particular that the consumption of local agricultural crops that using the same water sources for irrigation constitutes a dangerous additional route for the population living in the area under study.

REFERENCES

[1] Z. Ullah, H. Khan, A. Waseem, Q. Mahmood, U. Farooq, Water quality assessment of the River Kabul at Peshawar, Pakistan: Industrial and urban wastewater impacts, Journal of Water Chemistry and Technology 35(4) (2013) 170-176.

[2] M.T. Shah, J. Ara, S. Muhammad, S. Khan, S. Tariq, Health risk assessment via surface water and sub-surface water consumption in the mafic and ultramafic terrain, Mohmand agency, northern Pakistan, Journal of Geochemical Exploration 118(Supplement C) (2012) 60-67.

[3] E.J. Abdullah, Evaluation of surface water quality indices for heavy metals of Diyala River-Iraq, Journal of Natural Sciences Research 3(8) (2013).

[4] S. Khan, M. Shahnaz, N. Jehan, S. Rehman, M.T. Shah, I. Din, Drinking water quality and human health risk in Charsadda district, Pakistan, Journal of Cleaner Production 60(Supplement C) (2013) 93-101.

[5] S. Khan, R. Rauf, S. Muhammad, M. Qasim, I. Din, Arsenic and heavy metals health risk assessment through drinking water consumption in the Peshawar District, Pakistan, Human and Ecological Risk Assessment: An International Journal 22(3) (2016) 581-596.

[6] S. Muhammad, M.T. Shah, S. Khan, Health risk assessment of heavy metals and their source apportionment in drinking water of Kohistan region, northern Pakistan, Microchemical Journal 98(2) (2011) 334-343.

[7] S. Strachan, Trace elements, Current Anaesthesia & Critical Care 21(1) (2010) 44-48.

[8] P. Kavcar, A. Sofuoglu, S.C. Sofuoglu, A health risk assessment for exposure to trace metals via drinking water ingestion pathway, International journal of hygiene and environmental health 212(2) (2009) 216-227.

[9] H. Pekey, D. Karakaş, M. Bakoglu, Source apportionment of trace metals in surface waters of a polluted stream using multivariate statistical analyses, Marine Pollution Bulletin 49(9) (2004) 809-818.

[10] C. Knight, J. Kaiser, G. Lalor, H. Robotham, J. Witter, Heavy metals in surface water and stream sediments in Jamaica, Environmental Geochemistry and Health 19(2) (1997) 63-66.

[11] R.K. Sharma, M. Agrawal, F.M. Marshall, Heavy metal (Cu, Zn, Cd and Pb) contamination of vegetables in urban India: a case study in Varanasi, Environmental pollution 154(2) (2008) 254-263.

[12] A.K. Patra, S. Wagh, A. Jain, A. Hegde, Assessment of daily intake of trace elements by Kakrapar adult population through ingestion pathway, Environmental monitoring and assessment 169(1) (2010) 267-272.

[13] S. Khan, S. Rehman, A.Z. Khan, M.A. Khan, M.T. Shah, Soil and vegetables enrichment with heavy metals from geological sources in Gilgit, northern Pakistan, Ecotoxicology and Environmental Safety 73(7) (2010) 1820-1827.

[14] A. Waseem, J. Arshad, F. Iqbal, A. Sajjad, Z. Mehmood, G. Murtaza, Pollution status of Pakistan: a retrospective review on heavy metal contamination of water, soil, and vegetables, BioMed research international 2014 (2014).

[15] S. Khan, I.A. Shah, S. Muhammad, R.N. Malik, M.T. Shah, Arsenic and heavy metal concentrations in drinking water in Pakistan and risk assessment: a case study, Human and Ecological Risk Assessment: An International Journal 21(4) (2015) 1020-1031.

[16] M. Shahid, C. Dumat, B. Pourrut, G. Abbas, N. Shahid, E. Pinelli, Role of metal speciation in lead-induced oxidative stress to Vicia faba roots, Russian journal of plant physiology 62(4) (2015) 448-454.

[17] N. Shahid, S. Anwar, A. Qadir, H. Ali, F. Suchentrunk, H. Arshad, Accumulation of selected heavy metals in Lepus nigricollis from Pakistan, J. Basic. Appl. Sci. Res 3(11) (2013) 339.

[18] R.I. Alves, C.F. Sampaio, M. Nadal, M. Schuhmacher, J.L. Domingo, S.I. Segura-Muñoz, Metal concentrations in surface water and sediments from Pardo River, Brazil: human health risks, Environmental research 133 (2014) 149-155.

[19] M. Arora, B. Kiran, S. Rani, A. Rani, B. Kaur, N. Mittal, Heavy metal accumulation in vegetables irrigated with water from different sources, Food chemistry 111(4) (2008) 811-815.

[20] A.O. Affum, S.D. Osae, B.J.B. Nyarko, S. Afful, J.R. Fianko, T.T. Akiti, D. Adomako, S.O. Acquaah, M. Dorleku, E. Antoh, Total coliforms, arsenic and cadmium exposure through drinking water in the Western Region of Ghana: application of multivariate statistical technique to groundwater quality, Environmental monitoring and assessment 187(2) (2015) 1.

[21] X. Wen, Q. Yang, Z. Yan, Q. Deng, Determination of cadmium and copper in water and food samples by dispersive liquid–liquid microextraction combined with UV–vis spectrophotometry, Microchemical Journal 97(2) (2011) 249-254.

[22] P. Avino, G. Capannesi, A. Rosada, Ultra-trace nutritional and toxicological elements in Rome and Florence drinking waters determined by Instrumental Neutron Activation Analysis, Microchemical Journal 97(2) (2011) 144-153.

[23] S. Muhammad, M.T. Shah, S. Khan, Arsenic health risk assessment in drinking water and source apportionment using multivariate statistical techniques in Kohistan region, northern Pakistan, Food and Chemical Toxicology 48(10) (2010) 2855-2864.

[24] C.-S. Jang, Applying scores of multivariate statistical analyses to characterize relationships between hydrochemical properties and geological origins of springs in Taiwan, Journal of Geochemical Exploration 105(1) (2010) 11-18.

[25] T.S. Narany, M.F. Ramli, A.Z. Aris, W.N.A. Sulaiman, K. Fakharian, Spatiotemporal variation of groundwater quality using integrated multivariate statistical and geostatistical approaches in Amol–Babol Plain, Iran, Environmental monitoring and assessment 186(9) (2014) 5797-5815.

[26] A.A. Masoud, Groundwater quality assessment of the shallow aquifers west of the Nile Delta (Egypt) using multivariate statistical and geostatistical techniques, Journal of African Earth Sciences 95 (2014) 123-137.

[27] V. Uddameri, V. Honnungar, E.A. Hernandez, Assessment of groundwater water quality in central and southern Gulf Coast aquifer, TX using principal component analysis, Environmental earth sciences 71(6) (2014) 2653-2671.

[28] I.C. Yadav, N.L. Devi, D. Mohan, Q. Shihua, S. Singh, Assessment of groundwater quality with special reference to arsenic in Nawalparasi district, Nepal using multivariate statistical techniques, Environmental earth sciences 72(1) (2014) 259-273.

[29] N.K. Asare-Donkor, E.E. Kwaansa-Ansah, F. Opoku, A.A. Adimado, Concentrations, hydrochemistry and risk evaluation of selected heavy metals along the Jimi River and its tributaries at Obuasi a mining enclave in Ghana, Environmental Systems Research 4(1) (2015) 12.

[30] D.o.h.A.i. Dakahlia, (2014).

[31] http://en.climatedata.org/location/3998/.

[32] For full investigated the seasonal changes of contaminants in the focused area.

[33] Nitric acid 69.5% RPE – For analysis - ISO - ACS - Reag.Ph.Eur. - Reag.USP 1 l.

[34] B. Means, Risk-assessment guidance for Superfund. Volume 1. Human Health Evaluation Manual. Part A. Interim report (Final), Environmental Protection Agency, Washington, DC (USA). Office of Solid Waste and Emergency Response, 1989.

[35] P. Wongsasuluk, S. Chotpantarat, W. Siriwong, M. Robson, Heavy metal contamination and human health risk assessment in drinking water from shallow groundwater wells in an agricultural area in Ubon Ratchathani province, Thailand, Environmental geochemistry and health 36(1) (2014) 169-182.

[36] N. Shahid, Z. Zia, M. Shahid, H. Faiq Bakhat, S. Anwar, G. Mustafa Shah, M. Rizwan Ashraf, Assessing Drinking Water Quality in Punjab, Pakistan, Polish Journal of Environmental Studies 24(6) (2015).

[37] J. Nawab, S. Ali, U. Rehman, A. Khan, S. Khan, W. Khan, Health risk associated with heavy metals via surface and ground water consumption in Shangla district of northern Pakistan, Journal of Himalayan Earth Sciences 48 (2015) 62-73.

[38] U. Epa, EPA Integrated Risk Information System (IRIS) electronic database, US Environmental Protection Agency, Washington, DC (1996).

[39] M. Momodu, C. Anyakora, Heavy metal contamination of groundwater: the Surulere case study, Res J Environ Earth Sci 2(1) (2010) 39-43.

[40] A.M. Breure, B.A. Markert, H.G. Zechmeister, Bioindicators & Biomonitors: Principles, Concepts, and Applications, Elsevier2003.

[41] H. Itoh, M. Iwasaki, N. Sawada, R. Takachi, Y. Kasuga, S. Yokoyama, H. Onuma, H. Nishimura, R. Kusama, K. Yokoyama, Dietary cadmium intake and breast cancer risk in Japanese women: a case–control study, International journal of hygiene and environmental health 217(1) (2014) 70-77.

[42] D.S. Manta, M. Angelone, A. Bellanca, R. Neri, M. Sprovieri, Heavy metals in urban soils: a case study from the city of Palermo (Sicily), Italy, Science of the total environment 300(1) (2002) 229-243.

[43] H.S. Parizi, N. Samani, Geochemical evolution and quality assessment of water resources in the Sarcheshmeh copper mine area (Iran) using multivariate statistical techniques, Environmental earth sciences 69(5) (2013) 1699-1718.

[44] S. Varol, A. Davraz, Evaluation of the groundwater quality with WQI (Water Quality Index) and multivariate analysis: a case study of the Tefenni plain (Burdur/Turkey), Environmental Earth Sciences 73(4) (2015) 1725-1744.