Bull Environ Contam Toxicol (2011) 86:676–678
DOI 10.1007/s00128-011-0261-8

Risk Assessment of Dissolved Trace Metals in Drinking Water of Karachi, Pakistan

Zahida Karim

Received: 18 November 2010 / Accepted: 22 March 2011 / Published online: 30 April 2011

Abstract Health risk caused by the exposure to trace metals in water through different exposure pathways was investigated. Graphite furnace atomic absorption spectrometry was used for the determination of trace metals (nickel, copper, chromium, lead, cobalt, manganese and iron) in drinking water samples. The concentration of metals was compared with the world health organization (WHO) drinking water quality guideline values. Risk of metals on human health was evaluated using Hazard Quotient (HQ). Hazard quotients of all metals through oral ingestion and dermal absorption are found in the range of 1.11×10^{-2} to 1.35×10^{-1} and 8.52×10^{-5} to 9.75×10^{-2}, respectively. The results of the present study reflect the unlikely potential for adverse health effects to the inhabitants of Karachi due to the oral ingestion and dermal absorption of water containing these metals.

Keywords Trace metals · Risk assessment · Hazard quotient · Karachi

Drinking water pollution is one of the most severe environmental problems in the world. Elevated metal concentration in water supplies may pose a risk of adverse effect on human health. Ingestion of water containing significant amounts of metals may cause serious health effects varying from shortness of breath to several types of cancers in human beings (Kavcar et al. 2009).

Human health risk assessment is an effective approach to determine health risk levels posed by various contaminants (Wu et al. 2010). This method has been applied to assess the potential adverse health effects exposing to contaminated water (Hartley et al. 1999; Sun et al. 2007; Kavcar et al. 2009; Wu et al. 2010). Although ingestion is considered to be the primary route of exposure to chemical contaminants in drinking water, inhalation and dermal absorption are also increasingly taken into account as important exposure pathways.

The aim of this study was to determine the level of trace metals in drinking water of Karachi and to evaluate the health risk associated with exposure to these trace metals via oral ingestion and absorption through the skin.

Materials and Methods

Water samples were collected from 50 different sampling locations during July 2007 to May 2008. Triplicates samples were collected from each sampling location in polypropylene bottles. The samples were filtered through 0.45 μm membrane filter. The pH of the filtrate was set at 1 with the addition of a few drops of 65% nitric acid supra pure. For the determination of dissolved metal contents, water samples were analyzed directly without any pretreatment (ASTM 2000).

AAnalyst 700 Perkin–Elmer atomic absorption spectrometer equipped with graphite furnace, deuterium background corrector and AS-800 autosampler was used for the determination of trace metals in water samples. Standard solutions of understudy elements were prepared by the dilution of 1000 mg L^{-1} certified standard solutions of corresponding metal ions up to μg L^{-1} levels. The detection limits (3σ) were 5, 6, 4, 4, 1, 5, 10 μg L^{-1} for Ni, Cu, Cr, Pb, Co, Mn and Fe, respectively. In the spike recovery test sample is spiked with target analytes of interest.

Z. Karim (✉)
Department of Chemistry, University of Karachi,
Karachi, Pakistan
e-mail: zahidakarim@hotmail.com

Table 1 Descriptive statistics for the concentration of metals in tap water

Metals	Mean concentration ($\mu g\ L^{-1}$)	SD	RSD
Ni	37.53	16.32	0.43
Cu	121.70	24.20	0.20
Cr	11.93	9.77	0.82
Pb	6.05	4.14	0.68
Co	2.24	1.23	0.55
Mn	81.00	17.90	0.22
Fe	106.38	28.14	0.26

The percentages of recoveries for different metals were found in the range of 96%–102%.

The health risk assessment study was based on the United States Environmental Protection Agency (US EPA) guideline. Equations 1 and 2, adapted from US Environmental Protection Agency (US EPA 1989; De Miguel et al. 2007; Wu et al. 2009) were used to calculate the chronic daily intake through ingestion and dermal absorption pathways:

$$\text{CDI (oral)} = (\text{CW} \times \text{IR} \times \text{ABS}_g \times \text{EF} \times \text{ED})/(\text{BW} \times \text{AT}) \quad (1)$$

$$\text{CDI (dermal)} = (\text{CW} \times \text{SA} \times \text{K}_p \times \text{ABS}_d \times \text{ET} \times \text{EF} \times \text{ED} \times \text{CF})/(\text{BW} \times \text{AT}) \quad (2)$$

The HQ was calculated as follows:

$$\text{HQ} = \text{CDI}/\text{RfD} \quad (3)$$

Results and Discussion

The descriptive statistics for the concentration of metals in drinking water is shown in Table 1. Concentration of all the selected trace metals except for Ni, were below the WHO guideline values. Corrosion of household plumbing systems is an important source of trace metals found in tap waters (Kavcar et al. 2009). Brass fittings that are often coated with chromium-nickel compounds are also the major sources of Cu, Pb, Ni and Cr in the tap water. The phenomenon of corrosion and thus the concentration of metals in the drinking water depend on many factors such as pipe material, pH, presence of chloride and sulfates, concentration of DO, temperature and the residence time of water in the water distribution pipelines and in the plumbing systems.

Amongst three main routes of exposure (ingestion, inhalation, and dermal absorption), oral ingestion and

Table 2 Input parameters for exposure assessment of metals through oral ingestion pathway

Input parameters	Unit	Values	Reference
Concentration of trace metal in water (CW)	μg/L	–	–
Ingestion rate (IR)	L/day	2.2	Wu et al. (2009)
Exposure frequency (EF)	Days/year or events/year	365	Wu et al. (2009)
Exposure duration (ED)	Year	70	Wu et al. (2009)
Body weight (BW)	kg	70	US EPA (2004)
Average time (AT)	Days	25,550	Wu et al. (2009), US EPA (2004)

Table 3 Input parameters for exposure assessment of metals through dermal absorption

Input parameters	Unit	Values	Reference
Concentration of trace metal in water (CW)	μg/L	–	
Skin-surface area (SA)	cm^2	18000	US EPA (2004)
Permeability coefficient (K_p)	cm/hr	2×10^{-4} (Ni), 1×10^{-4} (Pb) 1×10^{-3} (Cu), 4×10^{-4} (Co) 2×10^{-3} (Cr), 1×10^{-3} (Mn) 1×10^{-3} (Fe)	US EPA (2004)
Exposure time (ET)	h/event	0.58	US EPA (2004)
Exposure frequency (EF)	Days/year	350	(US EPA 2004)
Exposure duration (ED)	Year	30	US EPA (2004)
Conversion factor (CF)	L/cm^3	1/1,000	Wu et al. (2009)
Body weight (BW)	kg	70	US EPA (2004)
Average time (AT)	Days	25,550	Wu et al. (2009), US EPA (2004))

Table 4 Reference dose for different metals (Wu et al. 2009)

Element	RfD_{oral} (μg/Kg/day)	RfD_{dermal} (μg/Kg/day)
Cr	3	0.015
Cu	40	12
Fe	300	45
Pb	1.4	0.42
Mn	20	0.8
Ni	20	5.4
Co	NA	NA

Table 5 Summary of the health risk assessment study of metals through oral route

Metals	CDI_{oral} (μg/Kg/day)	HQ_{oral}
Ni	1.1797	0.058983
Pb	0.18994	0.13567
Cu	4.4569	0.11142
Co	0.070366	NA
Cr	0.37473	0.12491
Mn	2.4550	0.12275
Fe	3.3402	0.011134

dermal absorption route were taken into consideration in this study. Exposure and risk assessments were carried out on the basis of US EPA guideline.

The input parameters and their values for calculating the chronic daily intake through oral ingestion and dermal absorption are mentioned in Tables 2 and 3, respectively. The values of the RfD_{oral} and RfD_{dermal} for the trace metals are listed in Table 4. Health risk assessment study of metals through oral and dermal route is summarized in Tables 5 and 6 respectively. The calculated CDI values of metals for oral ingestion and dermal absorption are found in the order of Cu > Fe > Mn > Ni > Cr > Pb > Co and Cu > Fe > Mn > Cr > Ni > Co > Pb, respectively. Non-carcinogenic health effects of different metals were determined by calculating the Hazard quotient (HQ). HQ > 1 suggests the probability of adverse health effects (Leung et al. 2008). However, the results of the present study indicate that the concentration of these metals may pose little or no adverse health effects to the inhabitants of Karachi via oral ingestion and dermal absorption of water.

The findings of this study are found in agreement with the previous studies. Wu et al. (2009) also reported that HQs of trace metals in drinking water were lower than unity, suggesting that these pollutants could pose minimum

Table 6 Summary of the health risk assessment study of metals through dermal route

Metals	CDI_{dermal} (μg/Kg/day)	HQ_{dermal}
Ni	0.00046011	0.000085206
Pb	0.000037080	0.000088286
Cu	0.0087010	0.00072508
Co	0.000054948	NA
Cr	0.0014631	0.097542
Mn	0.0047928	0.0059910
Fe	0.0065209	0.00014491

hazard to local residents in Nanjing, China. HQ_{dermal} were also found lower than the HQ_{oral}.

Acknowledgments I am grateful to the Department of Chemistry, University of Karachi for providing all the necessary research facilities.

References

ASTM (2000) Standard practice for measuring trace elements in water by graphite furnace atomic absorption spectrophotometry (D 3919-99). Water Environ Technol 11.01

De Miguel E, Iribarren I, Chacon E, Ordonez A, Charlesworth S (2007) Risk-based evaluation of the exposure of children to trace elements in playgrounds in Madrid (Spain). Chemosphere 66:505–513

Hartley WR, Englande AJ, Harrington DJ (1999) Health risk assessment of groundwater contaminated with methyl tertiary butyl ether (MTBE). Water Sci Technol 39:305–310

Kavcar P, Sofuoglu A, Sofuoglu SC (2009) A health risk assessment for exposure to trace metals via drinking water ingestion pathway. Int J Hyg Environ Health 212:216–227

Leung AOW, Duzgoren-Aydin NS, Cheung KC, Wong MH (2008) Heavy metals concentrations of surface dust from e-waste recycling and its human health implications in Southeast China. Environ Sci Technol 42(7):2674–2680

Sun F, Chen J, Tong Q, Zeng S (2007) Integrated risk assessment and screening analysis of drinking water safety of a conventional water supply system. Water Sci Technol 56:47–56

US EPA (1989) Risk assessment guidance for superfund volume I human health evaluation manual (part A)

US EPA (2004) Risk assessment guidance for superfund volume I: human health evaluation manual (part E). http://www.epa.gov/oswer/riskassessment/ragse/pdf/introduction.pdf

Wu B, Zhao DY, Jia HY, Zhang Y, Zhang XX, Cheng SP (2009) Preliminary risk assessment of trace metal pollution in surface water from Yangtze River in Nanjing Section, China. Bull Environ Contam Toxicol 82:405–409

Wu B, Zhang Y, Zhang X, Cheng S (2010) Health risk from exposure of organic pollutants through drinking water consumption in Nanjing, China. Bull Environ Contam Toxicol 84:46–50