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Research Article

Carcinogenic and Non-Carcinogenic Risk Assessment of Chromium in Drinking Water Sources: Birjand, Iran

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Abstract

The present study aimed to ascertain potential carcinogenic and non-carcinogenic risk of chromium concentrations to local population in Birjand, Iran. Environmental Protection Agency (US EPA) based on chromium concentrations the non-carcinogenic carcinogenic and risk assessment like Average Daily Dose (ADD), Hazard Quotient (HQ) and the Cancer Risk (CR) of being exposed to chromium by drinking water was calculated. The values for ADD, ADD_{Life}, HQ and CR were found. The results suggest that in Birjand, where people have consumed drinking water contaminated with Cr, 41.17 and 7.35% of samples have HQ>1 and 94.11% of samples have Cancer Risk (CR)>10^{6}. Industrial activities, such as industrial wastewater leaks, improper storage and disposal of industrial waste has been the release of chromium in soil and water.

Key words: Chromium, Birjand, risk assessment, water quality, chromium concentration

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Safe drinking-water is a basic need for human development, health and well-being and because of this it is an internationally accepted human right (WHO., 2001). This document provides guidance on the chemical safety of drinking-water. Chemical contaminants of drinking- water are often considered a lower priority than microbial contaminants, because adverse health effects from chemical contaminants are generally associated with long-term exposures, whereas the effects from microbial contaminants are usually immediate. Nonetheless, chemicals in water supplies can cause very serious problems (WHO., 2006).

Exposure to chromium occurs from ingesting contaminated food or drinking water or breathing contaminated workplace air. Chromium (VI) at high levels can damage the nose and cause cancer. Ingesting high levels of chromium (VI) may result in anemia or damage to the stomach or intestines. Chromium (III) is an essential nutrient (ATSDR., 2012).

Chromium (III) is an essential human dietary element and occurs naturally in many vegetables, fruits, meats, grains and yeast. Chromium (VI) occurs naturally in the environment from the erosion of natural chromium deposits but it can also be produced by industrial processes. There are demonstrated instances of chromium being released to the environment by leakage, poor storage or inadequate industrial waste disposal practices. Chromium compounds in either the chromium (III) or chromium (VI) forms are used for chrome plating, dyes and pigments, leather and wood preservation (EPA., 2010). Chromium (VI) and chromium (III) are covered under the total chromium drinking water standard because these forms of chromium can convert back and forth in water and in the human body, depending on environmental conditions (EPA., 2010). Measuring just one form may not capture all of the chromium that is present. In order to ensure that the greatest potential risk is addressed, EPA's regulation assumes that a measurement of total chromium is 100% chromium (VI), the more toxic form (EPA., 2010).

The Human Health Risk Assessment (HHRA) program provides state-of-the-science, independently peer reviewed human health assessments for existing chemicals and chemical mixtures that find their way into our air, water and land. The HHRA program plays a unique role in serving the needs of Environmental Protection Agency (EPA) programs by incorporating, integrating and coordinating the use of scientific information as a foundation for regulatory decision making (Clark and Barone, 2011).

Risk analysis consists of three stages; hazard identification (identifying risk agents, the conditions and events under which they potentially produce adverse consequences to people or the environment), risk assessment (describing and quantifying the risk) and risk evaluation (comparing and judging the significance of the risk). The purpose of these activities is to provide an important part of the information needed to support risk management (identifying, selecting and implementing appropriate actions to control the risk) (Covello and Merkhoher, 1993).

Due to the toxic properties and carcinogenesis effects of chromium and the health effects caused by the consumption of contaminated water to chromium for humans such as skin and internal cancers and to detect and prevent the occurrence of these effects determine the amount of health risk assessment and health effects predictions for different age groups is a necessary and vital.

According to the information of South Khorasan province water and wastewater company, 68 samples of wells and water distribution tanks Birjand collected that the concentration of total chromium in 37 samples has been higher than the WHO and INSO[1] standard level and 53 samples has been higher than the USEPA and due to chromium metal the potential in creating hazards. This study determines the cancer risk of non-cancerous diseases of lifetime caused by drinking water.

MATERIALS AND METHODS

Study area: Birjand has a cold desert climate with hot summers and cool winters. Precipitation is low and mostly falls in winter and spring (English Wikipedia).

Drinking water sampling: The present study, risk assessment of cancer diseases and non-cancerous diseases as a cohort analysis is that on the concentrations of total chromium in 68 samples of the wells, distribution network and reservoirs water by South Khorasan province water and wastewater company collected and measured, which is located in Table 1 summary of its results.

Approaches for assessing health risks

Participatory interviews: The exposure assessment consists of an estimation of the intake by human receptors of the chromium of potential concern. Estimation of the intake rate, or dose, involves the determination (by direct measurement and/or predictive modeling) of the chromium concentration in each relevant exposure medium and the estimation of the

[1]Iranian National Standards Organization

Fig. 1: Location Birjand in Iran

Table 1: Input parameter to characterize the ADD, HQ and carcinogenic risk value

	Parameters						
Age	IR (L day^{-1})	BW (kg)	EF (day/year)	ED (year)	AT (day)	Oral RFD (mg kg^{-1} day^{-1})	Oral SF (mg kg^{-1} day^{-1})
Child (0-6 years)	0.78	15	350	6	6	0.003	0.5
Adult (6-70 years)	2.5	80	350	20	26	0.003	0.5
Source	USEPA	USEPA	RAIS, USEPA	RAIS, USEPA	RAIS, USEPA	US EPA IRIS, 2012	US EPA IRIS, 2012

IR: Ingestion rate, BW: Body weight, ED: Exposure duration

intake rate for the respective medium, the combination of concentration and intake rate yields the estimated intake (Hopkins and Williams, 2011).

Average daily dose of chromium: Heavy metals exposure pathways including ingestion; inhalation and dermal contact (absorption). Chromium exposure pathway in the study, in comparison to oral intake (drinking water), however, all other pathway are considered negligible (Khan *et al*., 2013).

The ADD through water ingestion was calculated according to the modified equation from (Siriwong, 2006):

$$ADD = \frac{C \times IR \times ED \times EF}{BW \times AT}$$

where, ADD is average daily dose (mg kg^{-1} day^{-1}), C is the concentration of the contaminant in drinking water (mg L^{-1}), IR is the ingestion rate per unit time (L day^{-1}), ED is the exposure duration (years), EF is the exposure frequency (days/year), BW is body weight (kg), AT is the average time (years) (Table 1).

Health risk quotients of chromium: Quantitative non-carcinogenic risks are reported as hazard quotients (or hazard indices) by comparing predicted contaminant intakes directly to toxicity values in the form of reference doses (H2M Group, 1997). The exposed population is assumed to be safe when HQ<1 (H2M Group, 1997). Where the oral toxicity reference doses (RfD) value for Cr is 3.0E-03 mg kg^{-1} day^{-1} (Table 1).

The HQ for non-carcinogenic risk can be calculated by the following equation (Lim *et al*., 2008):

$$HQ = \frac{ADD}{RfD}$$

where, according to USEPA database preferred toxicity value for evaluating non-carcinogenic effects result from exposures. An estimate (with uncertainty spanning perhaps an order of magnitude or greater) of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime.

Carcinogenic risk assessment of chromium: Carcinogenic risks are expressed as the probability that an individual will develop cancer over a lifetime of exposure to a particular contaminant or to a mixture of contaminants (EPA., 1999). As with the non-carcinogenic risk characterization, carcinogenic risk characterization utilizes contaminant intakes and toxicity values (in the form of slope factor) to quantify risks (EPA., 1999). Slope factor is A plausible upper-bound estimate of the probability of a response per unit intake of a chemical over a lifetime. The slope factor is used to estimate an upper-bound probability of an individual developing cancer as a result of a lifetime of exposure to a particular level of a potential carcinogen (EPA., 1999). The risks of cancer are expressed in terms of the probability that one may develop cancer at a given lifetime exposure level, where in the life time exposure level (ADD_{life}) According to USEPA, AT is 70 years (H2M Group, 1997). The cancer risk can be calculated by the following equation (Kolluru *et al*., 1996; Wongsasuluk *et al*., 2014):

$$\text{Cancer risk} = ADD \times SF$$

Contaminants with a cancer probability risk greater than 10^{-6} were considered acceptable (H2M Group, 1997).

Statistical analysis: In order to calculate the risk of formulation in Excel Microsoft Office 2013 and descriptive statistics were used to calculate the SPSS software (version 16).

RESULTS AND DISCUSSION

The measured concentration of chromium by the Water and Sewage Company of South Khorasan province in 68 samples of the wells, distribution network and reservoirs water ranged from 2.01-116 µg L^{-1} (Table 2). Table 2 summarizes the calculated ADD, HQ, ADD_{Life} and cancer risk values for consumption of drinking water. The ADD for child and adult values ranged 1.2E-04-3.48E-03 and 1.99E-04-5.79E-03, respectively; the HQ for child and adult values ranged 4.0E-02-1.16 and 6.63E-02-1.93, respectively. The mean ADD_{Life} and Cancer Risk (CR) values for Cr were 1.87E-03 and 9.41E-04, respectively.

Most studies non-carcinogenic and carcinogenic risk assessment have been cross-sectional. But in this study with a one-year monitoring of water wells and water

Table 2: Concentration of Cr, Hazard Quotient (HQ) indices, average daily dose and cancer risk for Cr via drinking water

	Statistics				
Risk parameters	Age	Range	Mean	SD[b]	Units
Concentration of Cr N[a] = 68	-	2.01-116	45	33	µg L^{-1}
ADD for Cr	Child	1.2E-04-3.48E-03	1.43E-03	1.01E-03	mg kg^{-1} day^{-1}
	Adult	1.99E-04-5.79E-03	4.40E-03	1.69E-03	
HQ	Child	4.0E-02-1.16	0.478	0.337	-
	Adult	6.63E-02-1.93	0.8	0.565	
ADD_{Life}	-	1.6E-04-1.64E-03	1.87E-03	1.35E-03	mg kg^{-1} day^{-1}
Cancer risk	-	1.4E-05-2.32E-03	9.41E-04	6.86E-04	-

[a]Number of water samples, [b]Standard deviation

distribution network to non-carcinogenic risk assessment over the course of six years for children and for adults over the course of 26 years old and for the lifetime of the carcinogenesis risk assessment and action.

According to study of Karimpour and Shariat on heavy metals in the drinking water network in Hamedan found that concentration of lead, cadmium and chromium higher than standard limited (Karimpour and Shariat, 2000).

Adamu and colleagues in a study in 1992 on Heavy metal contamination and health risk assessment associated with abandoned barite mines in Cross River State, southeastern Nigeria,. Results showed that the average concentrations of Fe, Hg and Pb were above the required standard. The mean concentrations of Ba, Hg, Mn, Ni, Pb and Zn were higher in pond water compared to stream water. Contamination index and Nemerow pollution index indicated contamination at some mine sites, while human health risk assessment indicated unacceptable risk (hazard index (HI) values>1) for non-carcinogenic adverse health effect. The cancer risk of being exposed to Arsenic by drinking water from these sources did not exceed the acceptable risk of 1:10,000 for regulatory purposes (Adamu *et al*., 2015).

A study on the health risk assessment of arsenic in groundwater resources Kabudarahang West, Hamadan, Iran, 44.31 and 56.81% of sample, disease risk had for adults and children, respectively and 60.22% of sample, cancer risk had for lifetime (Rahmani and Farokhneshat, 2014).

According to study (a cross-sectional study carried out) in Health risks associated with heavy metals in the drinking water of Swat, Northern Pakistan carried out, the concentration of Cd, Cr, Ni and Pb above the limit WHO and EPA and the concentration of Cu, manganese and Zn in the range permitted (Khan *et al*., 2013).

Said Muhammad and colleagues conducted the study (a cross-sectional study carried out) on heavy metal (Cu, Co, Cr, Mn, Ni, Pb, Zn and Cd) concentrations of drinking water (surface water and groundwater) samples in Kohistan region, Northern Pakistan. The values for CDI were found in the order of Zn>Cu>Mn>Pb>Cr>Ni>Cd>Co and the values of HQ were <1 for all HM in drinking water samples indicating no health risk (Muhammad *et al*., 2011).

A study (a cross-sectional study carried out) on Assessment of Heavy Metals Health Risk of Groundwater in Ali Abad Katoul Plian, Iran. Results of health risk assessment of heavy metals for residents using the period was measured, for carcinogenicity diseases 2.32×10^{-4} individual and for non-carcinogenicity diseases 2.53×10^{-4} individual (Rajaei *et al*., 2012).

According to study (a cohort study carried out) (Rahmani and Farokhneshat, 2014) on non-carcinogenic risk assessment of chromium in water distribution network in Hamadan city: Iran, human health risk assessment indicated acceptable risk (Hazard Index (HI) values <1) for child and adult.

CONCLUSION

The results of the study, 68 samples of wells and water distribution tanks Birjand collected that the concentration of total chromium in 37 samples has been higher than the WHO and INSO standard level and 53 samples has been higher than the USEPA standard and potentially non-carcinogenic and carcinogenic risk of exposure pathway oral intake to residents. The results suggest that in Birjand, where people have consumed drinking water contaminated with Cr, 41.17 and 7.35% of samples have non-carcinogenic risk (HQ>1) for child and adults, respectively and 94.11% of samples have Cancer Risk (CR)>10^6 for residents In this study a exposure for the lifetime has been reported and no age breakdown of the parameters related to children and adults together and eventually a exposure for lifetime is reported. Receive chromium drinking water per unit of body weight in children more than in adults; As a result, children are more at risk of disease. South Khorasan Province Water and Wastewater Company officials required the continuous monitoring of heavy metals, sewage leak surveys necessary for the industry and old water distribution lines in order to prevent the potential non-carcinogenic and carcinogenic risk.

It is hoped that this study will provide a platform for researchers to study and action on other heavy metals, according to the susceptibility of the water resources of the city that they are not inform of their concentration is the limitations of this study.

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