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Health risk assessment and estimation of heavy metal Cd, Cr and Pb in drinking water of district Swat, Khyber-Pakhtunkhwa, Pakistan

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Abstract

Presence of heavy metals in ground water used for drinking purpose poses serious contamination hazard to human health**.** The aim of present study was to estimate concentration of selected heavy metals (cadmium, chromium and lead) in water used for drinking in District Swat, KPK, Pakistan. After taking opinion of the expert from Pakistan council research in water resources (PCRWR) and site survey, 160 ground water samples were collected from different sources and area of the District Swat. Concentrations of heavy metals; cadmium, chromium and lead in the water samples were estimated using atomic absorption spectrophotometer. Chronic daily intake (CDIs) and hazard quotient (HQ) for both adult and children was calculated. Minimum and maximum concentrations of cadmium in the water was 0.002 mg/L and 0.009 mg/L respectively, chromium in the water samples was 0.011 mg/L to 0.015 mg/L and concentration of lead in the water samples ranges from 0.03 mg/L to 0.8 mg/L. The maximum concentration of lead in the drinking water was higher than toxicity threshold limits of WHO and PCRWR drinking water standards. CDIs and mean concentration of heavy metals in water sources of the study area was observed in decreasing order, such as: Cd>Cr>Pb and the HQ of all heavy metals was lower than one. From study it is concluded that water used for drinking of the studied area was contaminated with heavy metals and constant ingestion of these heavy metals can affect the health of local community on the longer run.

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Introduction

Major part of earth surface is occupied by Water. Its volume is 1.41 billion m^3. Out of the total available natural aquatic resources, about 98% water is salty which is present in oceans, deep in underground basin and inland seas. As freshwater 2% is present, about 87% is locked in the form of icecaps and glaciers. The remaining is mostly present in ground water form (Rajvaidya and Markandey, 2005). Current population of Pakistan is 160 millions and in the year 2025 it is predicted to grow about 221 millions. This population increase will directly impact the water sector to meet the agricultural, domestic, and industrial needs. Now Pakistan has nearly exhausted its accessible resources of water and is on the edge of becoming a country with water deficiency. The availability of water per capita has been dropped from 5600 cubic meters to 1000 cubic meters.

The surface and ground water quality is not good and is becoming worse due to unnecessary use of fertilizers, insecticides, disposal of wastewater from industrial and unprocessed municipal water (PCRWR, 2002). Heavy metals like cadmium, arsenic, lead, chromium and mercury are very dangerous environmental pollutants. The presence of trace heavy metals in the atmosphere, soil, and water can cause serious problems to all organisms especially to human health (Taghipour *et al.*, 2012).

Heavy metals contribute to environmental pollution because of their unique properties; heavy metals do not leach from the topsoil and have the potential to move through food chain and accumulate in the tissues and organs (such as the kidneys, liver and bones) results in detrimental diseases. Heavy metals have specific signs of its toxicity.

For instance, mercury, arsenic, chromium, cadmium and lead poisoning have been associated with diarrhea, stomatitis, gastrointestinal disorders, hemoglobinuria, ataxia, paralysis, vomiting, convulsion, pneumonia and depression. Heavy metals could not only be toxic, its carcinogenic, neurotoxin, mutagenic and teratogenic effected have also be seen. Heavy metals have tendency to accumulate in the soil at toxic levels due to presences of wastewater for long time. Heavy metal transferred from soil to the ecosystem and ultimately affects human health through food and water supply (Taghipour *et al.*, 2012: Singh *et al.*, 2010).

Keeping in view the importance of clean drinking water and proper sanitation system in health care system it is important to identify determinants that are responsible for water borne illnesses. There is need to investigate causes of water borne illness and solution for these problems.

District Swat, particularly four union councils associated with it has not been explored for evaluation of heavy metal contamination of ground water used for drinking purpose so this study is design to develop background knowledge regarding water quality in these areas. Objective of current study was to estimate the heavy metal contamination in drinking water of District Swat, Pakistan.

Research methodology

Study Area

Swat district is situated in north-west of Pakistan. It is a beautiful and fertile area which is located in 34.09N latitude through 35.56 N and 72.07 N-E longitudes through 73.00E. It is bounded by district Chitral and Gilget in the north, Buneer at the south, Shangla at the east, and Dir and Malak and agency at the west. It has a population of nearly 1.249 million. Nearly 14% people are living in the cities and remaining people live in villages. There are 1246 villages with farm families of 145038 (Alam *et al.*, 2008).

Land area in use

In district Swat total land area is 5,337 square kilometers (sq. km). Cultivated Area is 242,296 acres. 227,336 acres is Irrigated Area and 337,804 acres is Forest Area (Agriculture Statistics of Pakistan, (2011)).

Population

In 1998 total population of district Swat was 1,257,602 individuals, with density of 236 persons/km^2. From 1981 to 1998 an average annual growth rate was 3.37% (DCR, 1998).

Economically active population

Out of the total population of district Swat, 19.38% were economically active in 1998. If we apply the same rate of employment to estimated current population, now there are 351,054 individuals which are economically active. 80.62% population is inactive economically. Out of the total population of district Swat, 34.34% are children which are below the age of 10. Domestic workers are 33.36%. Students are 8.14%. Economically inactive are 4.78% individuals. In 1998 the unemployment rates and participation of labor force were 30.42% and 29.51% respectively (DCR, 1998)

Language ethnicity and religion

In Swat district citizens from various ethnicities are found. These peoples are known to be independent, brave, generous and hospitable. Local language of Swat is Pashto and predominant religion is Islam. Some peoples belong to other religions, including Hinduism, Christianity, Sikhism and Qadiani/Ahmadi.

Flora

In district swat a lot of medicinal herbs and botanical plants are found. Nakhthar (*Pinus*), Eucalyptus, Toot (Morusmaraceae), Henthus, Sufaida (Popular), Paloosa (*Acacia modesta)* and Shesham *(Dalbergia sissoo)* are grown in plane as well as in hilly areas.

Fauna

Some common wild animals which are found in district Swat are Wolf, Deer, Jackal, wild mountain sheep, Monkey and black and brown bear. Due to deforestation most of these animals are now becoming scarce.

Climate condition

The climate in summer is pleasant and cool in winter. June, July and August are the hottest months of the year. In winter the minimum temperature is -1°C and during summer maximum temperature is 42°C.

Agriculture

The major income source of most of rural population in district Swat is agriculture which accounts for 50% of the economic activities.

The main irrigation source is Swat River for funneling water in various regions through canals built by government and community (Agriculture Statistics, Peshawar, 2008). The main crops are wheat, maize, soya bean, sun flower, rice paddy, some fruits and different variety of vegetables. e.g: Lady Finger, Potato, Carrot, Cauliflower, Tomato etc.

Strategy used for collection of water sample

First the study area was observed and after getting information about the study area strategy was prepared for sampling as adopted by Sakizadeh and Mirzaei (2016). Water samples were collected from the study area having four different union councils (UC), including UC Islampur, UC Sanghota, UC Manglor and UC Odigram.

Biochemical analysis for detection of heavy metals

Heavy metal analysis was carried out by using atomic absorption spectrophotometer. Concentration of Lead, Chromium and Cadmium was determined in drinking water samples. For the calibration of atomic absorption spectrophotometer various working standard were prepared previously described by Ali *et al* (2016). Cd, Cr, and Pb concentration in each drinking water sample was determined and results were noted.

Risk Assessment test for Human Health

Chronic daily intake index (CDI) for heavy metal was calculated by using an equation previously reported by US EPA (1999) and Nawab *et al* (2015).

$$CDI = C \times DI / BW$$

In Equation, C represents concentration of heavy metals in water (μg/L), DI is the average daily intake of water (2 L/day) by an individual and BW represents body weight (72 kg). For children it is consider being 1 L/day with an average body weight of 32.7 kg (Nawab *et al*., 2015; Khan *et al*., 2010; US EPA, 2011). Determination of noncarcinogenic risk of heavy metal was carried through Hazard Quotient (HQ) equation (Sakizadeh and Mirzaei 2016). HQ is the hazard quotient of heavy metals and if it exceeds one, the health risk of heavy metals could be considered high.

Incremental Lifetime Cancer Risk (ILCR) was also calculated for heavy metal exposure. If value of ILCR is ≥ 1 x 10^{-5}, risk of getting cancer could be associated with it.

Statistical analysis

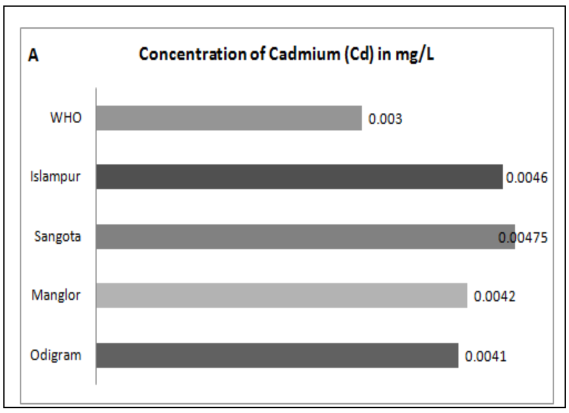
IBM SPSS Statistics (version 21) software was used for statistical analysis. Pearson correlation was used to correlate heavy metals with water sources. *p*-values were calculated by one way ANOVA to confirm any significant correlations among different heavy metals with respect to area. Significant correlation is denoted by * whereas highly significant correlation is denoted by **.

Results and discussion

Cadmium is found in low concentration in rocks, petroleum and coal. It can enter the surface and ground water when dissolve in acidic water. It can also enter in environment from metal plating, industrial discharge, water pipes, paints, mining waste, batteries and pigments, landfill leach ate and plastic stabilizers.

In human body biochemically it can replaces Zn and causes liver and kidney damage, high blood pressure, anemia, destroys red blood cells and testicular tissue. It is toxic to aquatic biota (Perlman, 2005). Cadmium in the water samples ranges from 0.001 mg/l to 0.009 mg/l in UC Islampur, UC Sangota and UC Odigram (Fig. 1).

According to WHO standards (2006) the permissible limit in drinking water for cadmium is ≤0.003 mg/L. The results obtained were higher than the recommended value of WHO guideline for heavy metal in drinking water (2006).



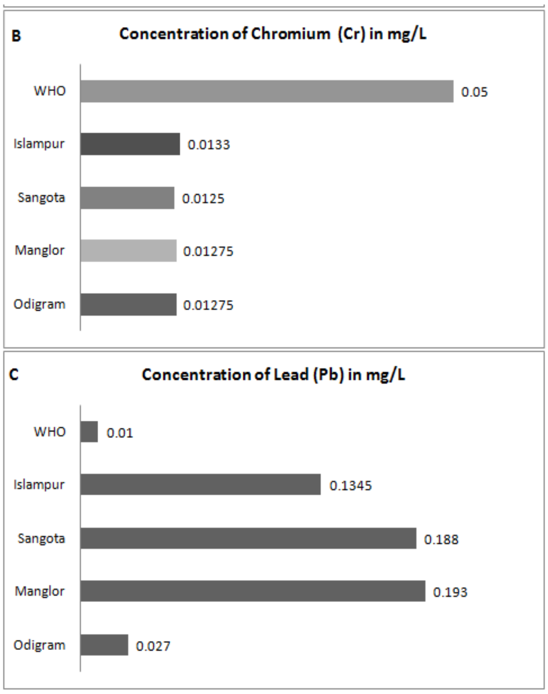


Fig. 1. Comparison of heavy metal concentration of the study area and WHO standards for drinking water, (A) Concentration of cadmium in drinking water sources of UC Islampur, UC Sanghota, UC Manglor and UC Odigram, (B) Concentration of chromium in drinking water sources of UC Islampur, UC Sanghota, UC Manglor and UC Odigram, (C) Concentration of chromium in drinking water sources of UC Islampur, UC Sanghota, UC Manglor and UC Odigram.

Chromium enters the environment from runoff of old mining operations and leaching into the ground water, mineral leaching, cement-plant emissions, fossil-fuel combustion and incineration of wastes.

It is used as cooling-tower water additive and in metal plating. Chromium III is nutritionally important element but Chromium VI at high concentration is toxic and can cause liver damage, kidney problems, respiratory damage, internal hemorrhage, dermatitis and ulcer on skin (Perlman, 2005).

Total concentration of chromium in drinking water is usually less than 2 µg/L, although the concentration as high as 120 µg/liter has been reported without causing any damage. In some epidemiological studies, an association has been found between chromium (VI) and lung cancer (WHO, 2006).

Amount of chromium in the water samples ranges from 0.010 mg/l to 0.017 mg/l in all union councils (Table 1). According to WHO guideline (2006) the permissible limits in drinking water for chromium is ≤0.05 mg/L. The results obtained were within recommended value of WHO and PCRWR standards for heavy metal concentration in drinking water (WHO, 2006; PCRWR, 2008).

Table 1. Heavy metal analysis of drinking water of four union councils (UC) of District Swat, Pakistan with WHO and PCRWR standards.

Area of water sample	Water Sample	Cadmium (Cd) mg/L (mean±SD)	Chromium (Cr) mg/L (mean±SD)	Lead (Pb) mg/L (mean±SD)	*p*-value
UC Islampur	Dug well	0.006±0.001	0.013±0.001	0.21±0.09	
	Tape water	0.004±0.003	0.015±0.001	0.12±0.05	
	Bore well	0.003±0.001	0.013±0.002	0.03±0.02	
	Hand pump	0.004±0.001	0.012±0.002	0.03±0.02	
	Spring	0.002±0.0007	0.014±0.002	0.32±0.012	0.01*
UC Sangota	Dug well	0.006±0.002	0.012±0.001	0.18±0.015	
	Tape water	0.002±0.000	0.013±0.001	0.28±0.018	
	Bore well	0.003±0.001	0.012±0.001	0.43±0.014	
	Hand pump	0.005±0.001	0.012±0.001	0.13±0.017	
	Spring	0.004±0.002	0.013±0.001	0.11±0.018	0.0008**
UC Manglor	Dug well	0.005±0.001	0.012±0.001	0.14±0.063	
	Tape water	0.003±0.001	0.013±0.001	0.8±0.125	
	Bore well	0.004±0.001	0.011±0.001	0.15±0.058	
	Hand pump	0.003±0.001	0.013±0.002	0.34±0.092	
	Spring	0.002±0.0007	0.013±0.001	0.19±0.016	0.01*
UC Odigram	Dug well	0.003±0.0014	0.013±0.0018	0.27±0.019	
	Tape water	0.003±0.0017	0.012±0.0009	0.18±0.06	
	Bore well	0.005±0.0028	0.012±0.0022	0.26±0.019	
	Hand pump	0.003±0.001	0.012±0.0015	0.32±0.010	<0.0001**
	Spring	0.0040.0014	0.013±0.0013	0.35±0.09	
Limit	Minimum	0.002	0.011	0.03	
	Maximum	0.009	0.015	0.8	
WHO standards		0.003	0.05	0.01	
PCRWR Standard		0.01	0.05	0.05	
HQ value		0.0004	0.0008	0.03	
ILCR value		0.0024	0.0012	0.0012	

World Health Organization (WHO 2011), Pakistan Council of Research in Water (PCRWR, 2008); ILCR (Incremental Lifetime Cancer Risk Calculation); HQ (Hazard Quotient Risk Calculation) Values are given in mean; p-value calculated by using one way ANOVA.

Lead is a cumulative poison. About 90% of the lead retained in the body enters the bones, from which it can be remobilized. The WHO recommends a maximum intake of ≤0.01 mg/L lead per person per week. Children's and infants, who are more susceptible than adults to lead poisoning, should have intake of < 0.01 mg/L per week. Public water supplies in most countries rarely contain clinically significant quantities of lead. Most samples with high levels have been taken from waters located near metal working industries (Trivedi and Raj, 1992). Lead in drinking water come up due to corrosion from the plumbing systems in the buildings. The measures taken to control the corrosion can reduce the amount of lead in drinking water. Lead in the water samples ranges from 0.03 mg/L to 0.8 mg/L (Table 1). According to WHO (2006) the permissible limits in drinking water for lead is 0.01 mg/L considering the drastic effects of lead.

The results obtained in current study were higher than the recommended value of WHO (2006). In previous study it was found that, concentration of Na, Zn and K in water samples of islampur area district Swat was in the permissible limit recommended by WHO, while concentration of Pb, Cr and Ni Ca and

Mg were high and above permissible limit, making the water of the area unsafe for drinking and irrigation (Hussain *et al.*, 2014).

The mean hazard quotient for heavy metals; Cr, Cd and Pb was 4×10^{-4}, 8×10^{-4}, 3×10^{-2}, respectively, which were lower than the results of the research conducted previously in Kohistan (Muhammad *et al.*, 2011). In another research the health risk of heavy metals in the groundwater sources in Swat, in the northern part of Pakistan, was investigated and the hazard quotient of all heavy metals was lower than one. In current study, the health risk of heavy metals in decreasing order was Cd >Cr >Pb and the hazard quotient of all heavy metals was lower than one, and is summarized in Table 1, which was similar to the other findings (Khan *et al.*, 2013). In summary, the hazard quotient for heavy metals in our research was lower than previous studies conducted in study area (Nawab *et al.*, 2015; Khan *et al.*, 2013).

Inter metal correlation among different water sources such bore well, dug well, hand pump, tape and spring water was performed using Pearson correlation coefficient and is summarized in Table 2. Correlation coefficient of heavy metal gives us valuable information about sources and pathway as previously describe by Khan *et al.*, 2013. From hand pump water source heavy metal shows significant ($p<0.01$) positive correlation Cr-Pb ($r=0.789$), while in spring water Cd-Cr showed significant positive correlation ($r=0.728$). Significant correlation among heavy metals shows that they originate from same contaminate or pollution source that is sediments, lead ore deposit and anthropogenic activities of the study area (Mohammad *et al.*, 2011).

Table 2. Pearson's correlations of heavy metals contamination of ground water from different sources used for drinking in district Swat, Pakistan.

Parameters	Cadmium	Chromium	Lead
Dug well			
Cadmium	1.00	0.098	-0. 496*
Chromium		1.00	-0.123
Lead			1.00
Tape water source			
Cadmium	1.00	0.041	0. 075
Chromium		1.00	0.050
Lead			1.00
Bore well source			
Cadmium	1.00	-0.480*	0. 373
Chromium		1.00	-0.270
Lead			1.00
Hand Pump water source			
Cadmium	1.00	-0.369	-0. 431
Chromium		1.00	0.789**
Lead			1.00
Spring water source			
Cadmium	1.00	0.728*	-0.268
Chromium		1.00	-0.248
Lead			1.00

† Pearson's correlation coefficients. *$p< 0.05$; Water sample from dug well, tape water, bore well, hand pump and spring.

Conclusion

It is concluded from present study that CDIs and average concentrations of heavy metals in drinking water sources of the study area was in decreasing order of Cd> Cr>Pb. Maximum concentration of lead in ground water sample used for drinking exceeded the permissible limits. Concentration of chromium and cadmium in drinking water samples was within permissible limit according to WHO and PCRWR standards.

The mean hazard quotients for the three heavy metals were lower than one, indicating that there was no instant risk due to the exposure to these heavy metals but constant ingestion of these heavy metals can damage the health of local community on the longer run.

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Conflict of interest

The authors declared that they have no conflict of interest.

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