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Source identification and assessment of physico-chemical parameters and heavy metals in drinking water of Islampur area, Swat, Pakistan

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Abstract

In Pakistan large number of population is using surface and groundwater for drinking purposes. The contamination of these water bodies by toxic metals and providing safe drinking water to public is a big challenge for the government especially in areas where there is geological control on ground water. The present study was conducted to assess the drinking water quality of Islampur area, Swat, in the close vicinity of mélange zone. Forty samples were collected from different ground water sources such as tube wells, springs, dug well sand hand pumps. These samples were analyzed for physical and chemical parameters including heavy metals (Pb, Zn, Ni and Cr).The results were compared with international standards, which show that most of the physico-chemical parameters such as total suspended solids, pH, salinity, total dissolved solids, chloride, sodium, potassium and zinc are within the permissible limits. Whereas electrical conductivity, alkalinity, hardness, lead, chromium, nickel, calcium and magnesium were above their permissible limit. In this respect the drinking water quality of the Islampur area, district Swat is unsafe for drinking purposes. This study indicates that the heavy metal contamination in the study area could be attributed to the mélange zone rocks.

Keywords: Islampur; Physico-chemical parameters; Heavy metals; Drinking water; Mélange zone; Health risk.

1. Introduction

Swat is one of the beautiful hilly areas full of natural resources and attractive site in the Khyber Pakhtunkhwa province, Pakistan (CPPR, 2010). It is bounded by Malakand district in the south, Chitral in the north, Shangla districts in the east, and Dir in the west. The study area is part of Swat district and is located between latitude 34°37´-34°43´N and longitude 72°19´ -72°26´ E as shown in Figure 1 (Sultan, 2006).

The safe drinking water supply is important in terms of both quality and quantity as it is essential to human existences (Peavey et al., 1985; Manahan, 1994). As the civilization evolved, human activity increases and changes occur in the nature of pollutants entering into watercourses (Gerard, 2007). These water contaminations are due to domestic waste, industrial effluents, municipal wastewater as well as unplanned urbanization and over exploitation of the natural resource, which distressed the drinking water quality (Clark et al., 1977; Sotirios et al., 2007). Due to these contaminations a variety of diseases are produced in human beings. The most common water borne diseases are typhoid, cholera, dysentery, diarrhea and hepatitis (Hamed and Sane, 1993; Yasser and Faheem, 2007). Due to the use of contaminated water in all over the world, about 2.2 billion people die every year (Azizullah et al., 2011) and 2.3 billion people suffering from water related diseases (Rizwanullah et al., 2009).

The drinking water in Swat is generally obtained from various sources, such as springs, tub wells, hand pumps and streams. The quality of drinking water sources in the area is uncertain and can be dominantly contaminated by geogenic and anthropogenic sources (Shah et al., 2010). Geology of the study area is comprised of the Indus suture zone (ophiolites and melanges) and Indian plate rocks in the area consists of metamorphosed Manglaur crystalline schists, Swat granite gneiss and overlaying metamorphosed Alpurai and Saidu schists (Kazmi et al., 1984). The ultramafic rocks of melange zone near Mingora are showing alteration dominantly indicated by serpentinization and locally by carbonation (Arif et al., 1996). The melange zone rocks especially ultramafic rocks in Swathas already been investigated to contribute high concentration of magnesium (Mg), chromium (Cr) and nickel (Ni) to drinking water of Kabal area which indicates geogenic sources for water contamination in the area (Begum, 2007). Anthropogenic contamination of soil has also been found in Swat valley which is causing contamination to underground and surface water. Heavy and light metals such as Cu and Cd that leached from contaminated soil are greatly affecting the quality ecosystem of the area (Nafees, 2009; Shah et al., 2010). There is also high concentration of total suspended solids (TSS), total dissolved solids (TDS), iron (Fe), copper (Cu) and manganese (Mn) in the drinking water of district Swat (Alam et al., 2008). The study area (union council Islampur) is lying closer to the mélange zone rocks. As these rocks in Swat area have already been reported as the source of contamination of heavy metals (Shah et al., 2010), therefore the possibility of contamination of drinking water in the area cannot be rated out. This study is an attempt to identify heavy and trace metals contaminations and related health risk assessment in the drinking water of the union council Islampur in Swat.

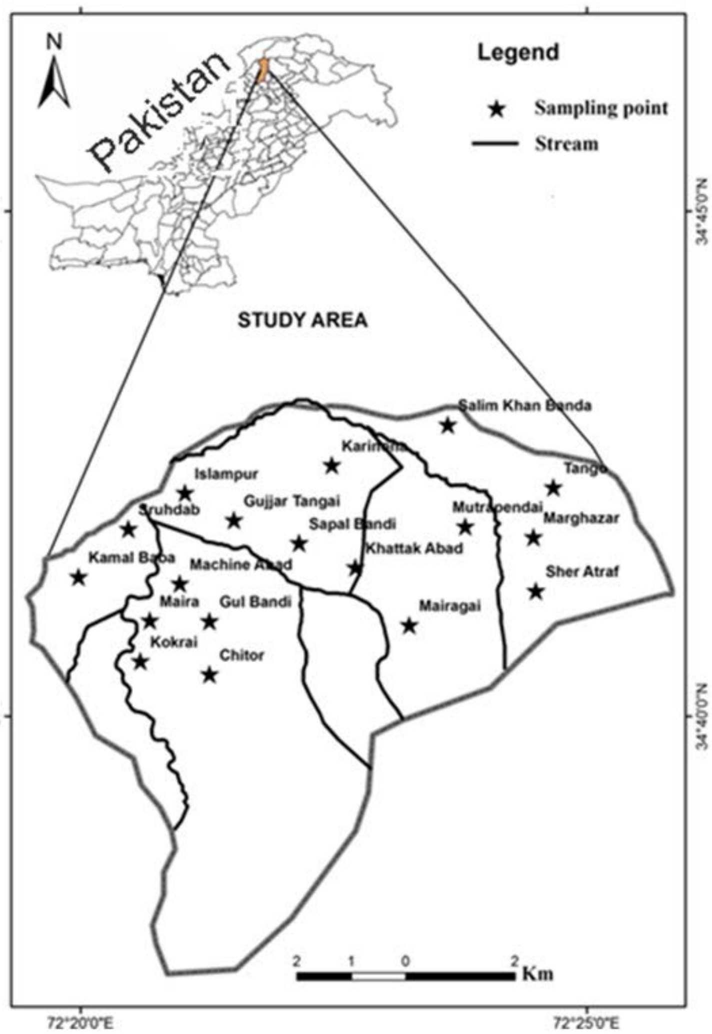

Fig. 1. Map showing location of sampling points in Islampur area of Swat (after Sultan, 2006).

2. Methodology

2.1. Samples collection

Field survey was conducted for collection of water samples from the union council Islampur, Swat. A composite sampling technique was applied for collection of representative samples. Random samples with one hour intervals were collected from a site, and then combine to form one composite sample as suggested by Vicki and Keller (1998). A total of forty representative water samples were collected from different sources such as tube wells (6), dug wells (4), springs (22) and hand pumps (4) from the union council Islampur, Swat.

2.2. Experimental work

Physico-chemical analyses of samples were carried out in the department of Environmental Sciences, University of Peshawar. Color, odor and taste of all the samples were determined through visual and organoleptical method. Physical parameter such as pH, electrical conductivity, salinity, were determined through elemental analyzer (InoLab99) on spot, while total dissolved solid sand total suspended solids were determined by gravimetric methods (APHA, 1992) in the laboratory. The chemical parameters such as hardness, chlorides and alkalinity were determined by using standard methods of titration (APHA, 1992). Heavy and trace elements (i.e. Ca, Mg, Na, K, Ni, Zn, Pb and Cr) analysis were carried out in selected number of samples (15) by using atomic absorption spectrophotometer (Perkin Elmer 700, USA) at the National Centre of Excellence in Physical Chemistry, University of Peshawar. All the reagents and acids used were of analytical grade. The Perkin Elmer reference methods and standard solutions were used for calibration and standardization of the instruments.

3. Results

3.1. Physico-chemical parameters

Results of physico-chemical parameters are shown in Table 1. The data indicated that pH and TSS of all the samples collected from tube wells, dug wells, hand pumps and springs were found within the permissible limits. Similarly chloride concentrations (4.7 to 173 ppm) in all samples were also found within the permissible limits set by WHO (2004). However hardness and alkalinity were found above their respective permissible limits set by WHO (2004) for the drinking water quality. The hardness in majority of the samples was found above the permissible limits with the highest concentration of 798.8 ppm as noted in water samples from Cham spring. Similarly alkalinity is also showing high concentrations for Cham spring with value of 404 ppm. The maximum electrical conductivity (EC) was found in the hand pump sample at Balawo (699 µS/cm). Salinity (0.01 to 0.03 ppm) in almost all samples is showing no greater variation.

3.2. Heavy and alkali metals

Statistical parameters (min, max, mean and standard deviation) of heavy and trace elements concentration found in the samples of the study area are given in Table 2. Among the heavy and trace metals Pb ranged from 0.42 to 1.66 ppm (mean: 1.04 ppm), Zn from < 0.02 to 2.40 ppm (mean: 1.20 ppm), Cr from 0.11 to 0.25 ppm (mean: 0.18 ppm), Ni from 0.03 to 0.09 ppm (mean: 0.06 ppm), Mg from 111.55 to 655.10 ppm (mean: 383.5 ppm), Na from <0.02 to 5.0 ppm (mean: 2.50 ppm), Ca from 21.25 to 141.72 ppm (mean: 81.62 ppm) and K from 1.0 to 8.0 ppm (mean: 4.50 ppm). The mean values of for majority of the elements are showing no significant variation. However Ca and Mg are showing relatively less concentration in springs as compare to other sources. These results indicated that majority of heavy and trace metals (except Zn and Na) were found above their permissible limits set by WHO (2004) as shown in Figure 2.

Table 1. Selected physico-chemical parameters in water sources of Union council Islampur, Swat.

Sample Site Name	pH	EC uS/cm	Salinity	Alkalinity mg/l	Hardness mg/l	Chloride mg/l	TDS mg/l
Kokri Spring	7.05	460	0.01	265.65	464.80	28.75	319
Kamal baba Spring	6.4	211	-	69.30	132.80	28.75	134
Karinona Spring	6.57	152	-	69.30	132.80	4.70	100
G.Tangy Spring	7.22	606	0.01	311.85	166	173	384
Mairgea Spring	6.91	13.50	0.01	323.40	448.20	19.17	311
Chinar Spring	6.91	345	0.01	219.45	481.40	19.17	312
Cham Spring	6.98	231	-	404.25	798.80	86.26	633
Shalmany Spring	7.50	225	-	254.10	315.40	9.58	204
Maira T.Well	7.20	430	0.01	161.30	249	9.58	192
M.abadT.Well	7.70	327	-	311.85	664	32.34	527
IslampurT.Well	6.61	190	-	138	315.40	4.70	172
SradabT.Well	6.96	801	0.02	346.50	713.80	62.30	527
SradabT.Well	6.97	801	0.02	150.15	298	4.79	171
IslampurT.Well	6.67	191	-	311.85	581	19.17	300
MairaT.Well	7.22	135.5	0.01	300.30	664	19.17	391
S.khanH.pump	7.21	230	-	231	315.40	9.58	209
BalawoH.pump	6.95	699	0.03	242.55	315.40	4.79	204
Khatak.abadH.pump	6.61	135	-	80.50	166	4.70	121
Khatak.abadH.pump	6.67	191	-	138	315.40	4.70	172
G.bandiH.pump	7.23	678	0.02	183	664	28.75	452
NirgwatH.pump	7.24	207	-	219.45	215	14.37	192
NirgwatD.well	7.24	207	-	219.45	215	14.37	192
Chitor D. well	7.70	327	-	138.60	298	23.96	206
ChinarD.Well	6.94	345	0.01	138.60	298	23.96	206
IslampurD.Well	6.61	135	0.01	80.50	315.40	4.70	121
WHO standard	6.5-8.5	-	-	-	< 500	200	1000

Table 2. Statistical parameters for heavy and trace elements concentration in drinking water of study area.

S.N	Parameters mg/l	minimum	maximum	Mean	WHO 2004
1	Pb	0.42	1.66	1.04	0.01
2	Zn	<0.02	2.40	1.20	3.0
3	Cr	0.11	0.25	0.18	0.05
4	Ni	0.03	0.09	0.06	0.02
5	Mg	111.55	655.10	383.55	50
6	Na	<0.02	5.0	2.50	200
7	Ca	21.25	141.72	81.62	75
8	K	1.0	8.0	4.50	-

The correlation matrix for both heavy and trace elements is shown in Table 3. The results indicated that significant Pearson correlation were found for Pb with Cr (0.910) and Ni (0.827); Ni with Cr (0.878), Mg with Ni (0.601) and Ca with Ni (0.568); Cr with Mg (0.520) and Cr with Ca (0.510); Ca with Mg (0.970). The strongest correlation between Ca and Mg, and Ni and Cr with majority of the elements (Fig. 2) clearly indicates the melange zone rocks are the major sources for the contamination of water bodies of Islampur area, Swat district. Scatter plot in figure 3 also confirm the strong positive correlation of Ni vs Cr and Ca vs Mg.

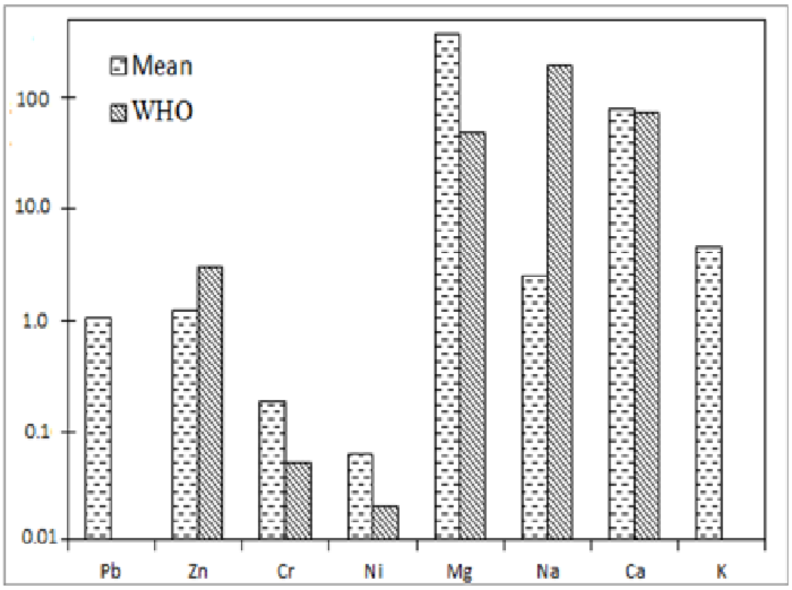

Fig. 2. Comparison of mean values for heavy and trace metals (ppm) with WHO (2004) standards.

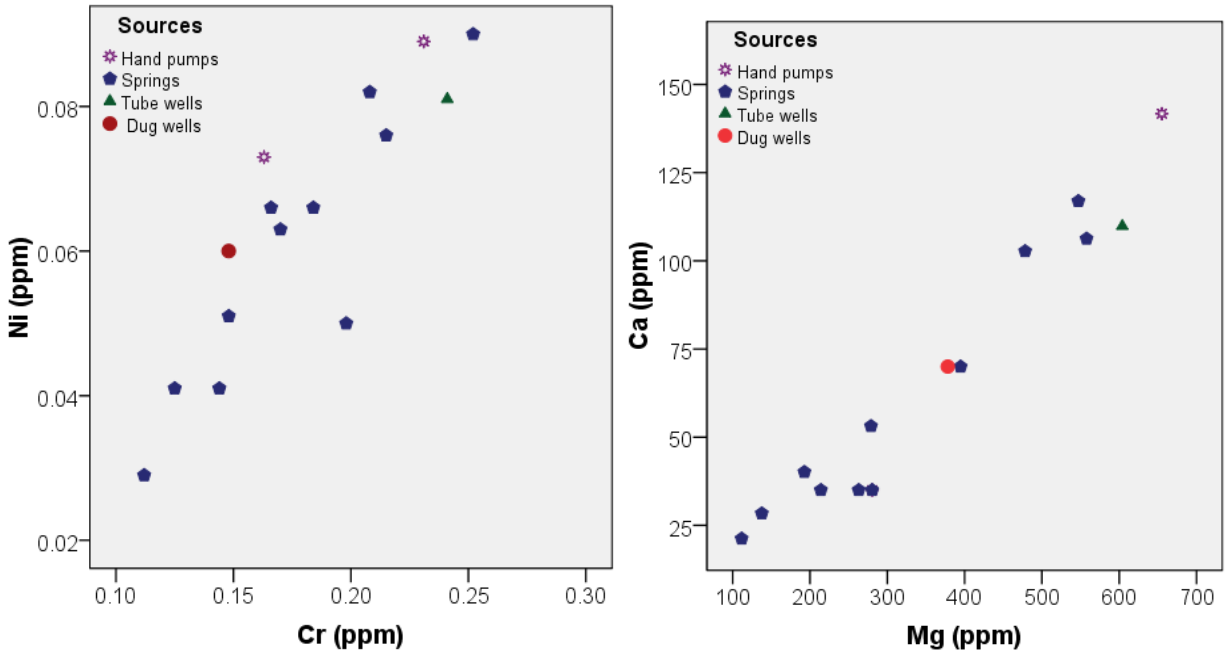

Fig. 3. Scatter plot showing correlation of Ni vs Cr and Ca vs Mg from different sources in the study area.

Table 3. Pearson correlations for heavy and trace metals in the study area.

	Pb	Zn	Ni	Cr	Ca	Mg	Na	K
Pb	1							
Zn	0	1						
Ni	.827**	0.21	1					
Cr	.910**	0.06	.878**	1				
Ca	0.3	0.4	.568*	0.510	1			
Mg	0.3	0.35	.601*	.517*	.970**	1		
Na	-0.11	-0.05	-0.08	-0.04	0.3	0.38	1	
K	-0.07	-0.23	-0.08	0.14	0.4	0.48	.753**	1

4. Discussion

4.1. Physico-chemical parameters

The excess of alkalinity in surface and ground water are usually caused by weak bases such as carbonates, bicarbonate and OH ions, which are released from carbonate rocks to the environment (Canete et al., 1987). The high concentration of alkalinity in wastewater is mainly due to anthropogenic sources. High concentration of alkalinity in water is manifested by a characteristic fringe of white salt at the edge of pipe, water tank, filtration plant and bank of stream. The consumption of high alkaline water can damage the stomach duct system (Manahan, 1994) and can be the main health problem in local population of the area.

The hardness above the permissible limit in the study area is correlated with high amount of Ca and Mg, and indicated that these elements are exceeded from their permissible limits (discussed in the later section). The human body skin may feel rough and uncomfortable upon the use of hard water. The calcium hardness has no side effect on human body and beneficial for heart patients (Peavey, 1985). But in some cases lower mortality from acute myocardial infarction can occur in adults with age of 50-74 (Rubenowitz et al., 2000). However Monarca et al. (2009) suggested that the intake of both Ca and Mg has no significant relationship with cardiovascular diseases.

4.2. Heavy and alkali metals

4.2.1. Source identification

Our discussion focuses mainly on source identification of heavy metals such as Pb, Ca, Mg, Ni and Cr that are causing contamination in the drinking water of the Islampur area. The alteration of ultramafic rocks due to serpentinization of serpentinite rocks and carbonation of talc carbonate rocks has already been reported in the nearby areas (Arif et al., 1996). The samples collected from the study area in the vicinity of melange zone rocks is expected to release majority of the elements to water sources in the study area. On that basis it is expected that majority of these elements such as Ni, Cr, Ca and Mg are also released to the environment by weathering and alteration due to close geological and geographical associations. Our results clearly indicated the geogenic sources of contamination in the study area. The anthropogenic sources for contamination in the area cannot be taken into account as less variation was found in the concentrations of these metals in tube wells, dug wells and hand pumps in comparison with springs. If we consider the absence of anthropogenic sources in the area, then how we will correlate Pb contamination in the area as no supporting evidence can also be seen from geology of the areas there is no industrial or any other anthropogenic sources are found in the area which could cause enhancement of these metals. However, one possible explanation is the existence Pb bearing minerals related to mineralization due to favourable conditions for mineralization along melange zones.

4.2.2. Possible health risks

Heavy and alkali metals released from the melange zone are the major cause of health risk for local population in the study area. Although some of the elements such as Ca and Mg are beneficial to human health as their daily intake can help to maintain the nutritional requirement of the body as well as minimize the loss of these elements during cooking (Luptakova et al., 2012). However, the elevated concentrations of both alkali and heavy metals are also the cause of health related problems. Small amount of these metals enter the human body through drinking water, food and air. Some of these metals are also essential to maintain the metabolic activity of human body, but upon the consumption of high concentration can lead to poisoning (Manahan, 1994). Heavy and alkali metals have the ability to bio-accumulate, and store faster than their degradation and excretion. Due to long term exposure and retention of heavy metals (Pb, Zn, Ni and Cr) in human body can cause acute and chronic damages to nervous system, liver and kidneys destruction, skin problem, ulceration and damages to circulatory and nerve tissues (Environmental corporation, 1988). The long term exposure of cadmium and chromium can cause renal dis-function, lung cancer and destroy respiratory system. The high concentration of lead can cause neuropsychiatric effects and damaging of blood tissues. The consumption of high concentration of Pb (100 µg/dL) in contaminated water can cause encephalopathy, increasing pressure skull, delirium, coma and headache (Henretig, 2006). Upon the high consumption of Ni, it could be induced toxicity and carcinogenicity in the human body. Nickel is also identified as haematotoxic, immunotoxic, neurotoxic, genotoxic, and pulmonary toxic and carcinogenic agent. Ni exposure can cause free radicals in human body and lead to modification of DNA, and effect enzymatic activity (Das, et al., 2008). The toxicity of heavy and trace metals are a potential threat and could not be deserted, but it is of utmost importance to be prevented (Liberman, and Gordon, 1989).

5. Conclusions

The overall situation of drinking water in Islampur, Swat is not satisfactory due to contamination by heavy and traces metals which are possibly related to geogenic sources of mélange zone rocks. Though the current study is based on limited number of samples but the results indicates that heavy and trace metal pollution could be a source responsible for health related problems in Islampur area of Swat.

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