Research Article

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Assessment of heavy metal contamination in the drinking water of muzaffarabad, Azad Jammu and Kashmir, Pakistan

Abstract

Safe and good quality potable water is a basic requirement for human existence, but if polluted can become the source of substances dangerous to human health. Azad Jammu and Kashmir is facing the problem of low quality of drinking water like other neighboring regions. Present study aimed to evaluate the heavy metal status in the drinking water of Muzaffarabad and outlying areas. Fifty three water samples were collected randomly from taps and spring waters of the study area and analyzed for six heavy metals (Copper, chromium, manganese, lead and zinc). Concentration of Cu, Fe, Mn and Zn were below the guideline values of WHO and GOP. Chromium and lead exceeded standard values of WHO and GOP in 21% (n=11) in each case. Overall 66% water samples were found potable, while in 33% samples heavy metal contamination surpassed permissible limit. The assessment shows quite a reasonable situation regarding heavy metal quality status of potable water.

Keywords: drinking water, heavy metal, muzaffarabad, AJ&K

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Introduction

Water is one of the utmost and fundamental requirements to sustain life on the planet earth. Being a universal solvent, water dissolves toxic organic and inorganic compounds that deteriorate its quality and influence consumer's health. Present day water sources, particularly surface waters are being polluted chiefly by domestic, agricultural, industrial, commercial wastes disposals in addition to natural contamination (e.g. trace metals) added due to the dissolution of natural substances and their subsequent transference in our flowing waters.[1–5] Globally water contamination is major cause of diseases and deaths and the situation become worst in developing countries.[1,6,7] Metal adulterations are mineral based which happen naturally or get in the watersheds through industrial discharges[8] comprising copper, chromium, iron, manganese and lead.[9] Such high levels of these trace metals in water reveal their load in environment. Ingestion of higher amounts of metals through water route is of extreme significance in risk assessment studies in human health.[4,10–12] and such substantial quantity may consequence in alarming adverse health effects ranging from shortness of breath to numerous types of cancers.[13,14] Copper, lead and zinc enter the water, usually through pipelines,[3,4,8,12,16,17] air pollution[18,19] and water stagnation in distribution system may cause significant rise in their levels.[13]

Lead is a potent neurotoxin and its occurrence in drinking water is the cause of various adverse health issues in humans. Acute poisoning of lead results in dis–functioning of kidneys, hypertension, brain, CNS, reproductive system, bones and blood enzyme changes.[6,14,20,21] Higher copper concentration is immunotoxic; may cause metabolic and gastrointestinal complications and disturbs the liver and brain specifically in patients of Wilson's disease.[3,14,20,22,23]

Higher chromium concentration is carcinogenic as well as genotoxic.[9,24–26] Elevated levels of iron is connected with increasing risks for cancer, heart disease, and other illnesses like arthritis, endocrine problems, diabetes and also liver disease.[21] Although manganese exists in water as a groundwater mineral yet may also enter through underground pollution sources. It may become obvious in tap water (at concentrations higher than 0.5mg/L) by imparting color, odor, or taste to the drinking water although health effects from Mn are not alarming until concentrations cross approximately 5mg/L.[27]

Zinc concentration in tap water can be much higher as a consequence of its leaching through piping and fittings.[11,16,20,27] In humans higher concentration of Zn may cause demyelinating disease.[23] Provision of safe drinking water to the public is one of the major concerns in the water sector in Pakistan. According to Farooq et al.[28] approximately 40% of the total population has no access to potable water. WHO recommends that drinking water must be treated in order to make it free from toxic chemicals and pathogens.[20] In Azad Jammu and Kashmir, more than eighty percent of illnesses have been recognized as due to the consumption of poor quality of water, supplied from surface and ground water sources.[6] Assessed drinking water quality of Bagh[18] and Rawalkot[6] has also shown elevated contamination of trace metals and organic pollutants in this region.

Materials and methods

Study area

Muzaffarabad (Lat:34.35º; Long:73.47º) is the capital of the Azad Jammu and Kashmir (Figure 1) situated at the convergence of the Neelum and Jhelum rivers, surrounded by mountains. District Muzaffarabad covers an area of 2496sq.km. (19% of the total area of the AJK state. The population of Muzaffarabad is 0.770million comprising 21% of the total population of AJK. Average rainfall is 1300mm with sub–tropical climate.[29] The study area is bounded by Garri Dopatta in the East (24km away from city), Lohar Gali (2km) in West, Pattika (17km) in the North, and Kohala (32km) in the South.[29]

Figure 1 Map of the study area.

Sample collection

Samples were collected randomly from different house hold taps and natural spring sources of Muzaffarabad. Water flow was allowed for two to three minutes to discharge the stagnant water prior to collection of tap sample. Collecting bottles were pre washed with distilled water before collection. Bottles were completely filled with water and caps were replaced instantaneously.[30] After collection samples bottles were kept in a cooler having ice slurry and transported to the laboratory.

Analytical methods

Copper, chromium, manganese, lead and zinc concentration in collected water samples were detected using atomic absorption spectrophotometer (AAS) (GBC 932plus) following Bartram & Balance.[31] The detection wavelength for Cr, Cu, Fe, Pb, Mn and Zn were 357.9nm, 324.7nm, 248.3nm, 217.0nm, 279.5nm and 213.9nm respectively. Standard solutions were prepared using commercially available Lab grad stock solutions of 1000mg/L (Merk) of respective metals (3111B, APHA).[32] Detection limit for each metal was calculated according to Fatoki and Awofolu[33] and Javaid et al.[6]

Statistical analysis

Descriptive statistics was used for data analyses. T–test was used to compare findings of study with WHO and GoP guidelines value. MS Excel and Statistix (ver. 8.1) software were used to analyze data.

Results and discussion

The drinking water quality of Muzaffarabad was assessed by taking samples from tap and spring waters sources of Muzaffarabad. Total of fifty three drinking water samples were collected. People use surface water for variety of purposes including drinking water, cooking and basic hygiene, in addition to agricultural and industrial activities. The obtained results were compared with WHO and GOP standards established for drinking water. Result depicted that the drinking water of Muzaffarabad is tasteless, colorless and odorless meeting WHO and GOP limits and showing good aesthetic properties. Drinking water of other cities of Azad Jammu and Kashmir i.e. Rawalakot and Bagh was found to be colorless, tasteless and odorless.[6,18] Metal concentrations varied in different drinking water of Muzaffarabad ranged from 0.0 to 0.718 mg/L (Fe). Out of 6, maximum 5metals detected in only one sample (Lachraat), whereas three metals detected in the majority (43%) of the samples, followed by 2 (23%), 4 (15%) and 1 (11%). Three drinking water samples (6%) showed no detection of any metal (Appendix I).

Chromium

Chromium was detected in 16 drinking water samples whereas 8 samples showed no concentration of chromium. In 29 samples, the concentration remained below the detection limit (Figure 2). Detectable concentration ranged between 0.032 (±0.028)mg/L to 0.363 (0.064)mg/L with mean value of 0.111 (±0.0224) mg/L (Appendix II). Maximum value found in Garhi Dupatta 0.363 (±0.064)mg/L

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followed by Kruli 0.207 (±0.017)mg/L and Dulai 0.194 (±0.020) mg/L, and minimum concentration detected in Pir Chinasi was 0.032 (±0.028)mg/L (Figure 3; Appendix I). Chromium showed equal distribution in tap and spring water. 30 % spring water samples have shown Cr concentration as compared to 29% of tap water samples (Figure 4). Highly significant difference ($p<0.01$) was noted between the Cr concentration found in the collected samples and WHO and GOP allowable limits (Appendix III). Chromium concentration in drinking water may be due to natural and anthropogenic activities including painting, cooling tower water and chromate production.[34] About 20 % of the samples have raised concentration of Cr when compared with the standard value set by WHO (Figure 2). In other parts of the Pakistan e.g. KPK and Sindh, 75 percent and 25 percent drinking water samples had exceeded the guideline value of Cr respectively.[35] Highly significant difference ($p<0.05$) was observed between WHO limit and samples' chromium concentration. Non–point source pollution resulted in increased concentration of drinking water of Muzaffarabad. Its equal distribution in tap and spring waters of the study area showed equal environmental burden. Chromium concentration in spring water resulted from dissolution from parent rock strata,[34,36] generally humans are exposed to an average of 0.2–2µg chromium per liter in drinking water through this natural erosion.[26]

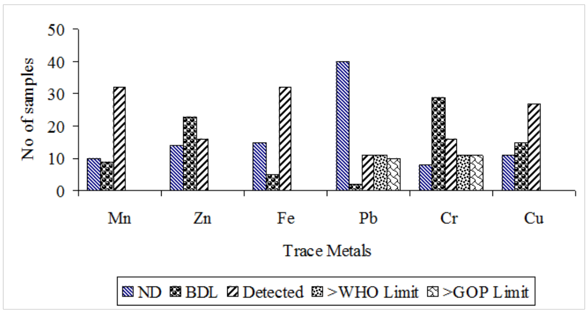

Figure 2 Status of different trace metals in drinking water samples of Muzaffarabad. (BDL)

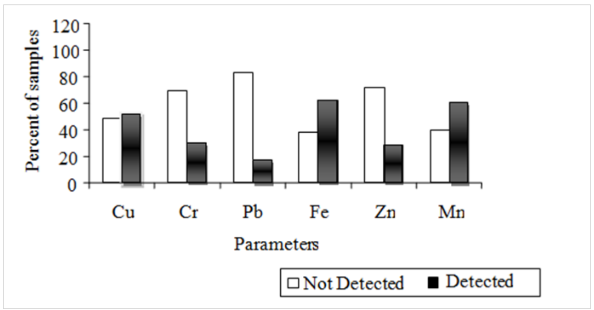

Figure 3 Detection percentage of different parameters in spring water of Muzaffarabad.

Copper

Copper detected in 27 drinking water samples while in 15 samples remained below the detection limit and in 11 samples it was not detected (Figure 2). Detectable concentration ranged between 0.038 (±0.043) to 0.211 (±0.017)mg/L with mean value of 0.1307 (±8.52E–03)mg/L. Maximum Cu concentration observed in Pitika Park 0.211 (±0.017) mg/L followed by Mera Parsacha 0.205 (±0.010) mg/L and Narool 0.180 (±0.010) mg/L and the lowest concentration was noted at Makri Plant 0.038 (±0.043) mg/L. Fifty two percent samples of spring water and 43 percent samples of tap water were contaminated with copper (Figure 4). Non–significant difference was observed between the guideline values of WHO and GOP and copper concentration measured in the collected samples (Appendix III). Copper plumbing is a major source of increased copper in drinking water.[18] The pitting of copper is usually linked with hard waters.[37] The mean concentration of Cu (0.130mg/L) noted in collected samples of Muzaffarabad could be compared with average value of KPK (0.20mg/L), Karachi (0.31mg/L),[34] Rawalakot (0.70 to 2.79mg/L[6] and Bagh (1 to 4mg/L).[18] Maximum Cu concentration in tap water was reported to be 1.2mg/L in Chile, 4.8mg/L in USA, 1.9mg/L in India,[11] 0.01mg/L in Nigeria.[3–5] and 4.6mg/L in Hong Kong.[10] In our study sixty two percent spring water samples and fifty seven percent tap water samples showed Cu concentration. This indicated the dissolution of metal in both types of water through common source.

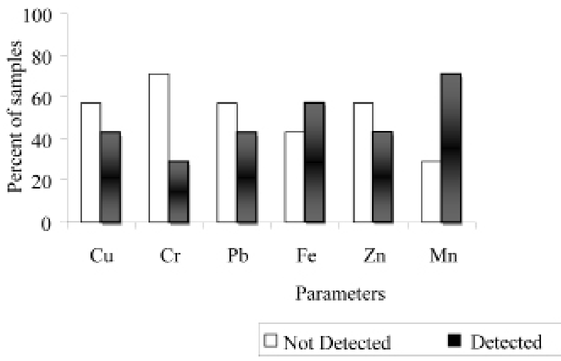

Figure 4 Detection percentage of different parameters in tap water of Muzaffarabad.

Iron

Iron found in thirty two drinking water samples and only five water samples showed concentration of iron below the detection limit while it was not present in fifteen samples (Figure 2). Detectable iron concentration ranged from 0.096 (±0.048)mg/L to 0.718 (±0.065) mg/L with mean concentration of 0.279 (±0.0315)mg/L (Appendix II). Maximum Fe concentration was found in Narool samples i.e. 0.718 (±0.065)mg/L followed by Malsi 0.661 (±0.059)mg/L and Barsala 0.625 (±0.028)mg/L. Minimum concentration was detected in Makri plant 0.096 (±0.048)mg/L (Appendix I). No significant difference ($p>0.05$) was observed between sample concentration of iron and WHO guideline, that showed the concentration of iron in drinking water falls within WHO and GOP permissible limits (Appendix III). Iron was equally distributed in 57% and 62% samples of tap and spring water of the study area respectively (Figure 4). Iron is abundantly found element in the earth's crust, although present usually in minor concentrations in natural water. The formation of ferric precipitate makes drinking water objectionable. None of the water sample crossed WHO limit for iron in the collected samples which could be compared with surface water of KPK and Sindh where 25% and 100% samples had crossed the critical WHO level for Fe respectively.[35] The concentration of Fe fluctuated between 0.01–1.29mg/L in water samples of KPK and 0.13–2.91mg/L in Karachi,[35] 5.3–12.18mg/L in Nigeria[3–5] and 0.01 to 18.86mg/L in Rift valley Ethiopia.[38]

Lead

Lead detected in 11 samples while its concentration remained below the detection limit in 2samples (Figure 2). The lead concentration ranged between 0.029 (±0.008)mg/L to 0.665 (±0.178) mg/L with mean concentration of 0.1612 (±0.0542)mg/L (Appendix I). Maximum lead concentration was in Dulai 0.665 (±0.178)mg/L followed by Bandi Kareem Haider 0.293 (±0.039)mg/L and Jalalabad 0.129 (±0.123)mg/L and minimum concentration 0.029(±0.008) mg/L was detected in Sundh Gali, Muzaffarabad. Lead was not present in 40 drinking water samples (Appendix I). Highly significant difference ($p<0.01$) was witnessed between the guideline value of lead and drinking water concentration found in the samples of Muzaffarabad (Appendix III). Ten drinking water samples showed higher Pb concentration as compared to the GOP guidelines value for drinking water in Pakistan (Appendix I). The common sources of lead are lead–based paints, traditional remedies, cosmetics and leaded petrol.[5,39] Lead was detected in 43 percent samples of tap water which was higher than spring water samples. The noted concentration of Pb in our study (0.029–0.665mg/L) was higher than the surface water of KPK (0.02–0.38mg/L) and Karachi (0.09–0.32mg/L)[35] and lower than Rawalakot (1.82 and 4.66mg/L)[6] and Bagh (<3to7mg/L).[18] Lead concentration was significant when compared to WHO guidelines value.

In the study area, there is no identified point source of metals contamination. Higher concentration of lead in some of the water samples is due to atmospheric pollution because Pb is one of the important environmental toxin which is documented by other studies.[3–6,18,40] Atmospheric concentration could rise due to use of leaded petrol which is very common practice in Pakistan and Azad Jammu and Kashmir.[6,41] Higher concentration of Pb in tap water of Dolet colony 0.089 (±0.019)mg/L and Domel 0.089 (±0.020)mg/L resulted by corrosion from distribution pipes. Corrosion is the chief source of Pb contamination in drinking water.[4–6,35,40]

Manganese

Manganese detected in thirty two samples. Detectable concentration of Mn ranged between 0.013 (±0.004)mg/L and 0.246 (±0.065)mg/L with mean value of 0.0684 (±0.0542)mg/L (Appendix II). Highest concentration was detected in Garhi Dupatta 0.246 (±0.065)mg/L followed by Tali Mandi 0.224 (±0.037)mg/L, Majhoi 0.206 (±0.037) mg/L and lowest Mn concentration was in Makri Plant 0.013 (±0.004) (Appendix I). There was no detection of this metal in 10 samples while in nine samples concentration was below the detection limit (Figure 2). Non–significant difference was observed between the concentration of Mn in samples and guideline value established by WHO[20] and GOP.[42] Manganese concentration range in drinking water of Muzaffarabad varied from 0.031 to 0.246mg/L which was less than the drinking water of Rawalakot (0.54 to 4.73mg/L),[6] Bagh (0.7–2mg/L)[18] and KPK (0.01–1.11mg/L).[35] Manganese showed almost identical distribution pattern in tap and spring water samples. It was detected in 71 percent and 61 percent samples taken from tap and spring water respectively. Non–significant difference was observed between guideline values set by WHO and GOP and manganese concentration in the collected water samples. In our study Mn concentration is attributed to under–ground pollution sources.

Zinc

Zinc observed in 16 samples and remained below the detection limit in twenty three samples (Figure 2). Detectable concentration of zinc ranged from 0.058 (±0.021)mg/L to 0.405 (±0.269)mg/L with mean concentration of 0.144 (±0.0238)mg/L (Appendix II). Highest concentration of zinc detected in Plate tap was 0.408 (±0.269) mg/L followed by Police Line 0.265 (0.239)mg/L and Makri Plant 0.231 (±0.160)mg/L, whereas lowest Zn concentration was in Malsi 0.058 (±0.021)mg/L (Appendix I). There was no detection of Zn in fourteen samples of the study area (Figure 2). Concentration of Zn showed non–significant difference when compared to the guideline value of WHO (Appendix III). Zinc is also among the most common elements in the earth's crust.[4–6,43] Zinc compounds are widely used in paints, ceramics, batteries, fabrics, sun block etc. and released in large quantities during production.[27,43] The measured values for Zn (0.05–0.405mg/L) in drinking water could be compared with Bagh (1–3mg/L),[18] Nigeria (0.3–0.49mg/L)[3–5] Rawalakot (0.56 to 2.69mg/L)[6] and Rift valley Ethiopia (0.01 to 5.14mg/L).[38] Zinc was distributed more frequently in tap water than spring water. Forty three percent samples of tap water and 28 percent samples of spring water were contaminated with Zn. Its concentration in tap water was due to leaching from piping and fittings.[6,18,44] No significant difference was observed between WHO guideline value and Zn concentration in the drinking water of Muzaffarabad.

Conclusion

On the bases of results, following conclusions are made, that the nature of parameters studied in which concentration exceeded from the WHO and GOP guideline values indicated the elevated concentration is attributed to natural as well as anthropogenic activities. Excess lead concentration in tap water indicated mostly corrosion of faucets or water utility pipes in distribution system. Levallois et al.[14] supported the view that lead can be released into water from lead–containing service lines, leaded pipes, solders, and faucets in buildings. In spring water, it was due to environmental pollution such as automobiles and welding material. Chromium concentration ranged from below the detection limit to higher than permissible limit. In spring water, Cr concentration is added through sediments whereas tap water concentration showed environmental burden of this metal. Metals concentration like iron, zinc, copper and manganese observed within the range of WHO limits.

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Conflicts of interest

The authors declare that there are no conflicts of interest.

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Appendices

Appendix I Concentration of trace metals in drinking water samples in Muzaffarabad AJK.

		Trace metals (Means±SD)											
	WHO guideline value	Cu (3mg/L)		Cr (0.05mg/L)		Pb (0.01mg/L)		Fe (1-3mg/L)		Zn (3mg/L)		Mn (0.5mg/L)	
	GoP guideline value	Cu (2mg/L)		Cr (0.05mg/L)		Pb (0.05mg/L)				Zn (5mg/L)		Mn (0.5mg/L)	
S. No.	Sampling Site												
1.	Bandi Kareem Haider	ND		ND		0.293	-0.039	BDL		ND		BDL	
2.	Bandway	0.133	-0.006	0.179	-0.066	ND		ND		ND		0.127	-0.023
3.	Bansara	ND		ND		ND		BDL		ND		ND	
4.	Barsala	0.043	-0.006	ND		ND		0.625	-0.028	BDL		BDL	
5.	Chall Pani	0.082	-0.012	ND		ND		0.197	-0.026	BDL		0.084	-0.009
6.	Channal Bang	0.067	-0.031	BDL		ND		0.254	-0.014	0.098	-0.017	0.023	-0.008
7.	Chattar Klass	0.152	-0.009	ND		ND		0.504	-0.039	ND		0.09	-0.019
8.	Darbar	BDL		ND		ND		0.107	-0.04	0.19	-0.269	0.02	-0.024
9.	Dhanni Mai Sahiba	0.126	-0.007	ND		ND		0.342	-0.036	BDL		0.08	-0.015
10.	Doba Sayedan	0.126	-0.004	ND		ND		0.382	-0.031	BDL		0.097	-0.021
11.	Dolet Colony (tap)	BDL		0.07	-0.014	0.089	-0.019	BDL		BDL		BDL	
12.	Domail (tap)	ND		ND		0.089	-0.02	BDL		ND		0.03	-0.023
13.	Dulai	BDL		0.194	-0.02	0.665	-0.178	0.116	-0.099	BDL		0.014	-0.01
14.	Garhi Dupatta	0.17	-0.007	0.363	-0.064	ND		BDL		ND		0.246	-0.065
15.	Ghorri	ND		0.082	-0.034	0.12	-0.082	0.144	-0.058	ND		0.028	-0.028
16.	Gorri	0.113	-0.005	ND		ND		0.323	-0.033	0.172	-0.055	ND	
17.	Hasan Abad	ND		BDL		ND		BDL		0.079	-0.098	0.018	-0.016
18.	Hassan Galian	ND		0.087	-0.055	ND		BDL		0.123	-0.109	0.029	-0.05
19.	Hundi Peran	0.12	-0.008	ND		ND		0.228	-0.017	BDL		ND	
20.	Jalalabad	BDL		ND		0.129	-0.123	0.128	-0.038	0.095	-0.124	BDL	
21.	Kaju	0.098	-0.01	BDL		ND		BDL		ND		0.047	-0.01
22.	Kal Panah	0.106	-0.016	0.035	-0.01	ND		0.397	-0.014	BDL		0.175	-0.042
23.	Khashkar	BDL		0.075	-0.001	ND		0.129	-0.017	0.09	-0.031	0.013	-0.011
24.	Kohala	BDL		ND		0.096	-0.007	0.148	-0.044	0.19	-0.043	0.022	-0.018
25.	Kruli	0.099	-0.012	0.207	-0.017	ND		0.516	-0.02	BDL		0.125	-0.018
26.	Lachraat	0.111	-0.012	0.062	-0.012	ND		0.465	-0.025	0.061	-0.026	0.015	-0.004
27.	Langerpura	0.151	-0.017	ND		ND		ND		ND		ND	
28.	Lower Chatter	BDL		BDL		ND		BDL		ND		BDL	
29.	Madina Market	0.112	-0.013	ND		0.114	-0.021	BDL		ND		0.019	-0.009
30.	Majhoi	0.178	-0.005	ND		ND		0.206	-0.018	ND		0.206	-0.037
31.	Makri Plant	0.038	-0.043	BDL		ND		0.096	-0.048	0.231	-0.16	0.013	-0.004
32.	Malsi	0.169	-0.006	ND		ND		0.661	-0.059	0.058	-0.021	ND	
33.	Mera Parsacha	0.205	-0.01	ND		ND		0.102	-0.032	ND		0.112	-0.011
34.	Narool (tap)	0.18	-0.01	ND		BDL		0.718	-0.046	BDL		0.029	-0.006
35.	Pajgran	ND		0.043	-0.018	ND		BDL		BDL		ND	
36.	Patti Naka	ND		ND		ND		ND		BDL		0.022	-0.028
37.	Pir Chinasi	ND		0.032	-0.028	ND		BDL		0.067	-0.011	BDL	

Table continued

		Trace metals (Means±SD)											
	WHO guideline value	Cu (3mg/L)		Cr (0.05mg/L)		Pb (0.01mg/L)		Fe (1-3mg/L)		Zn (3mg/L)		Mn (0.5mg/L)	
	GoP guideline value	Cu (2mg/L)		Cr (0.05mg/L)		Pb (0.05mg/L)				Zn (5mg/L)		Mn (0.5mg/L)	
S. No.	Sampling Site												
38.	Pittika Bazar	0.126	-0.01	BDL		ND		0.174	-0.039	ND		0.046	-0.006
39.	Pittika Park	0.211	-0.017	BDL		ND		0.301	-0.014	ND		ND	
40.	Plate (tap)	BDL		0.103	-0.008	ND		0.119	-0.03	0.408	-0.269	ND	
41.	Police Line (tap)	BDL		BDL		ND		0.19	-0.055	0.265	-0.239	0.027	-0.016
42.	Qadeemi Chishma	0.119	-0.017	ND		ND		0.415	-0.021	ND		ND	
43.	Rara	ND		ND		ND		ND		ND		ND	
44.	Rashid Abad	ND		0.037	-0.063	0.077	-0.022	0.121	-0.021	ND		BDL	
45.	Satpeyali	ND		ND		BDL		0.291	-0.057	ND		0.047	-0.014
46.	Sethi Bagh	ND		0.042	-0.01	0.072	-0.018	BDL		ND		0.017	-0.025
47.	Shawai Nala	BDL		ND		ND		0.11	-0.092	BDL		BDL	
48.	Subri	0.177	-0.007	ND		ND		0.29	-0.019	ND		0.103	-0.016
49.	Sundh Gali	ND		ND		0.029	-0.008	BDL		ND		BDL	
50.	Talimandi	0.154	-0.01	ND		ND		BDL		ND		0.224	-0.037
51.	Thori (park)	BDL		ND		ND		0.131	-0.054	0.066	-0.015	0.02	-0.019
52.	Thotha	ND		ND		ND		BDL		0.124	-0.027	0.126	-0.021
53.	Upper Chattar	0.162	-0.008	0.165	-0.051	ND		ND		BDL		0.033	-0.007
	Detection Limit	0.03		0.01		0.01		0.09		0.05		0.01	

ND, not detected; BDL, below detection limit

Appendix II Descriptive statistics for different study parameters.

Parameters	**N**	**Mean**	**SD**	**SE Mean**	**C.V.**	**Min.**	**Med.**	**Max.**
Cr (mg/L)	16	0.111	0.0898	0.0224	80.876	0.032	0.0785	0.363
Cu (mg/L)	27	0.1307	0.0443	8.52E-03	33.879	0.038	0.126	0.211
Fe (mg/L)	32	0.2791	0.1784	0.0315	63.919	0.096	0.217	0.718
Mn (mg/L)	34	0.0684	0.0656	0.0112	95.84	0.013	0.0315	0.246
Pb (mg/L)	11	0.1612	0.1798	0.0542	111.56	0.029	0.096	0.665
Zn (mg/L)	16	0.1448	0.0951	0.0238	65.683	0.058	0.096	0.408

Appendix III One sample t-test comparing the means of the parameters with WHO parametric values.

	WHO				**95% Conf interval**		
Parameter	**guidelines**	**N**	**Mean**	**SE**	**Lower**	**Upper**	**t- value**
Copper	2mg/L	27	0.1307	8.519E-03	0.1132	0.1482	-219.42
Chromium	0.05mg/L	16	0.1110	0.0224	0.0632	1.588	2.72**
Iron	10mg/L	32	0.2791	0.0315	0.2148	0.343	-86.29
Manganese	0.5mg/L	34	0.0684	0.0112	0.0456	0.0913	-38.36
Lead	0.01mg/L	11	0.1612	0.0542	0.404	0.2820	2.79**
Zinc	2mg/L	16	0.1448	0.0238	0.0941	0.1955	-78.02

SE, standard deviation; ** Highly significant