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Biological and heavy metal investigation for drinking water quality assessment of Drosh and Asheriat areas of District Chitral, Pakistan

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Abstract

Current study has been conducted to investigate the water quality of Drosh and Asheriat District Chitral. About 70 water samples were taken from different drinking water sources including springs, rivers, streams, tube wells from Drosh and Asheriat. All the water samples were analyzed for total coliform, feacal coliform and heavy metals by using standard methods. The concentration of heavy metals were determined in water samples using Graphite Furnace equipped Atomic Absorption Spectrometer (AAS-700) of Perkin Elmer. The results of total and fecal coliform analysis which are the recommended indicator for water quality showed that maximum probability number of the water samples ranges from 0-1800 counts/100mL while WHO standard for drinking water quality is no E. coli in 100mL of water sample (0 counts/100mL). The concentration of Ni in was found above the permissible limit in 8% drinking water samples from Drosh and in 7% drinking water samples from Asheriat area of district Chitral. While the rest of the heavy metals like Cd, Mn, Co, Cr, Zn and Pb were within the guide line values of WHO and maximum permissible limits set by USEPA. Results of this study highlight the problem of the area that needs further study.

Keywords: Heavy metals, Fecal coliform, Chitral, Pakistan, WHO, USEPA.

1. Introduction

Fresh water is an essential component for existence of life which comprises 3% of the total amount of water present on the surface of earth and only a small fraction (0.01%) of this freshwater is accessible for human to fulfill their required needs (Hinrichsen and Tacio, 2002). There are many places on the earth where freshwater has become a scarce and overexploited natural resource leading towards many social and environmental concerns (UNSCO-WWAP, 2006; Falkenmark, 2008). Global population increase is rapid while the accessibility of freshwater is declining day by day due to lack of awareness in common masses, urbanization, industrialization, lack of proper management and experts professionals. Heavy metals from both geogenic and anthropogenic can possibly contaminate different surface as well as ground water sources resulting in declining of quality (Krishna et al., 2009). Some of heavy metals high intake have been reported as highly toxic for human as well as aquatic life for example cadmium (Cd), lead (Pb), manganese (Mn) and chromium (Cr) while others like copper (Cu), cobalt (Co) and zinc (Zn) are essentially required for normal body growth and functions of living organisms and suggested as food supplements (Ouyang et al., 2002). Ingestion of drinking water having significant amounts of metals can lead towards many adverse health issues ranging from breathing, digestive, cardiac, skin problems, to kidney and lung and other types of cancers (Cantor, 1997; Calderon, 2000; Xia and Liu, 2004; Dogan et al., 2005). Heavy metals are significant pollutants due to their toxic and persistence nature and bio-accumulative properties within different environmental compartments (Pekey et al., 2004).

Microbial contamination of water including coliforms and Escherichia coli (E. coli), a type of fecal coliform bacteria, are considered to be the most important drinking water quality microbiological parameters (Dufour, 1977). The occurrence of E. coli in drinking water indicates that fecal material of human or other animals are the sources of contamination. E. coli which was first introduced in 1983 as an indicator of fecal contamination is now recommended by the U.S. Environmental Protection Agency (US-EPA) as a better indicator of fecal pollution than other coliform for drinking water quality evaluation (US-EPA, 1986). Municipal wastewater discharge, human and animal waste dumping sites, septic and surface runoff are possible sources of E. coli contamination (An et al., 2002). There are several environmental factors which can influence the growth and decay of these microorganisms including nutrient supply, temperature, dissolved oxygen and pH (Curtis et al., 1992).

Bacteriological contamination of drinking water has been regarded as the most important problem for the drinking water quality in Pakistan (PCRWR, 2005). Several water sources including shallow ground water aquifers, rivers and springs are highly polluted with bacteriological infection (Aziz, 2005). According to WHO reported standard for drinking water quality there should be no E. coli in 100mL of water sample (0 counts/100mL) (WHO, 1993). The current study was therefore under taken in lower part of district Chitral to account for micobiological analysis including fecal coliform tests and heavy metal analysis of drinking water sources from Drosh and Asheriat area.

Results of this study highlight the problem and recommends special attention to the area and further study of the surrounding areas.

2. Geographical location of study area

Geographically district Chitral is bounded to the east by Gilgit-Baltistan, to the northwest by Afghanistan and district Dir is in the south. Population of the district Chitral is 447362 and average annual growth rate is 1.80 from 1998 to 2017. The study area (Drosh, Nagar and Asherat) is situated on the main Dir-Chitral road along the Chitral River, and is located in the south of Chitral District which lies between 35º 20′ – 35º 40′ N and 71º 30′ -71º 50′ E, with an elevation range of 1094 to 7726. These are among the small towns of district Chitral which has a number of small villages and towns some of which can be easily accessed by main roads.

Chitral district is divided in two parts, the southern hilly areas and northern plain areas. The southern Chitral consist of coniferous forests, while the northern Chitral and inner valley have noticeably very less trees (Khan et al., 2013). Tirichmir, the world's fifth highest mountain peak (25,000 feet) is also located in Chitral (DCR, 1998). Chitral district is located in the dry temperate zone of Pakistan (Champion et al., 1965). Weather condition in summer is hot with a maximum temperature of 44.4°C while in winter season the temperature falls below the freezing point up to -0.6°C. The average recorded annual rain fall is 414.9 millimeters (mm). During winter snowfall can be sometimes quite heavy and up to two feet snow can be accumulated while at high elevations annual snowfall can reach as high as 20 meters (70 ft).

3. Geology of the study area

District Chitral constitute the northwestern part of Pakistan and is situated in the distant eastern part of the Hindu-Kush range. Geologically the study area is located on the southeastern side of the Main Karakoram Thrust (MKT), which is also known as Northern Suture Melange zone (NSM). There are mostly mafic-ultramafic rocks in this area. Rocks of the northern part of Kohistan island arc are also present in the study area. There are Cretaceous meta-sedimentary and volcanic rocks intruded by granites, diorites and tonalities. The basic lithology belong to the Gawuch, Purit and Drosh formations (Fig. 1). The Kohistan Batholith which lies to the southeast of these rocks, is composed of un deformed acidic plutons including granites and granodiorites (Calkin et al., 1981).

4. Methodology

4.1. Sampling

Water samples from different water sources including dug wells, hand pumps, streams, tube wells, and springs were collected in brand new and clean plastic (polyethylene 200 ml) bottles for trace metal analysis of representative water sources in lower Chital. Random sampling technique along with duplicate sample collection for quality control purpose have been applied. These polyethylene bottles were rinsed with double deionized water before its use for water sample collection. Each representative sample was stored in two bottles, one un-acidified for biological analysis while, and the other was acidified with 5% HNO3 (Analytical Grade) for elemental analysis (APHA, 1992). Temperature, electric conductivity and pH were recorded in the field. The samples locations were noted down by using a GPS (e-Trex Garmin GPS).

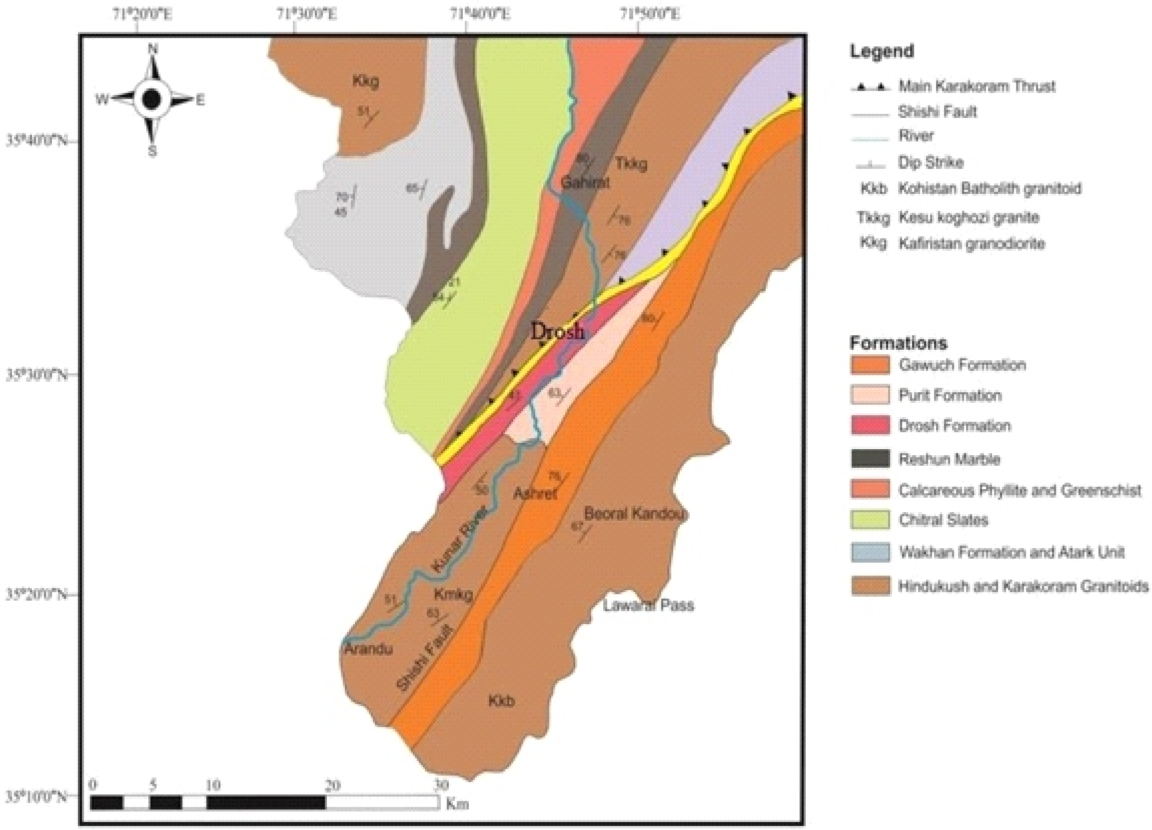

Fig. 1. Elevation based location map of the study area (selected districts) in Pakistan.

4.2. Chemical analysis

All the collected water samples were transported to the Geochemistry Laboratory in National Centre of Excellence in Geology, University of Peshawar where further detailed analysis were performed. All the samples, procedural blanks, along with standard reference material were analyzed with the help of standard methods for heavy metals including Mn, Cu, Pb, Zn, Ni, Co, Cr and Cd by using Atomic Absorption Spectrometer (A Analyst 700) equipped with graphite furnace and Mercury Hydride System.

4.3. Microbiological analysis

Hundred milliliters (200 ml) of water sample from stream, springs, tube wells and hand pumps was collected in labeled sterile bottles. Air spaced of at least one-fourth of the total volume was maintained in the sampling bottles. These bottles were kept in the refrigerator before analysis (APHA, 1992).

To test drinking water, both the presumptive and confirmed tests are performed. Standard methods and US-EPA (U.S. Environmental Protection Agency) commend a minimum number of five tubes for presumptive tests. These probable tubes showing gas formation are further used to immunize confirmed tubes. The most probable number (MPN) of coliform method is used for organism determination and positive confirmed tubes. A statistical estimation of the coliform concentration is an indicator of the water quality. Fecal coliform test may be expected to differentiate between coliforms of fecal origin and coliforms from other sources.

5. Results and discussion

5.1. Heavy metals in water

Results of analysis of water samples of Drosh and Asheriat for heavy metals (Ni, Pb, Cd, Co, Cr, Cu and Zn) are shown in Table 1. The concentrations of majority of the elements such as Pb, Cd, Co, Cr, Cu, Zn, Mn, in water samples of both Asheriat and Drosh were within permissible limits set by WHO and USEPA. However the concentration of Ni, in some samples from both these areas are showing high concentration as compare to WHO and USEPA standards (Fig. 2).

Nickel concentration was found in the range of 0.03- 247.90 ppb and 0.02- 87.27 ppb in the water samples of Asheriat and Drosh respectively. Some of the samples from both these areas have high concentration when compared with WHO (2004) standard. In Asheriat highest concentration (247.90 ppb) was found in spring water sample while in Drosh highest concentration (87.27 ppb) found in tank water.

High concentration of nickel may produce some allergy, immune problems, kidney, liver, and genetic defects along with lung and nasal cancer (Ross, 1995). According to the IARC evaluation (IARC, 1997) there are sufficient evidences in humans for the carcinogenicity of nickel sulfate and of the combinations of nickel sulfides and oxides encountered in the nickel refining industry. Hence, they can be classified in Group 1, carcinogenic to humans. As there is inadequate evidence in humans for the carcinogenicity of metallic nickel, it may be carcinogenic to humans. It is a well-known fact that chronic exposure to heavy metals and metalloids even at a very low level are capable of producing very deleterious health problems (ATSDR, 2003, 2007, 2008).

5.2. Factor analysis and source identification

Water sources mainly get polluted as a result of human activities but some of the inorganic toxic chemicals released by rocks enter into streams, river, or percolate into ground aquifers and cause contamination in the water bodies (William et al., 2005). It is therefore mandatory to understand the sources of contaminants. Many authors have used factor analysis to determine the sources of contaminants in similar type of environment (Elias et al., 2018; Guan et al., 2018; Mirzaei et al., 2018). The above factor analysis technique was used elsewhere to examine the metal pollution sharing and source identification (Helena et al., 2000).

Factor analyses for water of Drosh and Asheriat are given in Table 2 & 3. In Drosh, factor 1, factor 2, factor 3, factor 4 and factor 5 accounts for 14.62%, 14.09%, 12.52%, 11.01%, 9.7% of the total variance respectively (Table 2). Factor 1 had high loading of Ni and Pb. The association of Ni and Pb could be attributed to the presence of known Pb mineralization and the weathering of mafic and ultramafic rocks. In factor 2 highest loading of K and Mg were found which could be due to geogenic source. In factor 3 highest sharing of Fe was observed which possibly influenced by erosion and leaching of local mafic-ultramafic rocks. In factor 4 highest loading of Zn and Na were found while in factor 5 highest contributions of Cr and Mn were found influenced by geogenic sources.

In Asheriat, Factor 1, factor 2, factor 3, factor 4 and factor 5 accounts for 19.06%, 14.53%, 13.35%, 12.40%, 9.19% of the total variance respectively (Table 3). Factor 1 had high loading of Pb and Zn. The close association of Pb and Zn could be attributed to known Pb mineralization in the vicinity of study area. In Factor 2 highest loading of Cd was found which could be due to geogenic source. In factor 3 highest sharing of Na and Mg were observed which is also influenced by local geogenic sources. In factor 5 highest loading of Zn was found also associated with known mineralization in the vicinity.

Table 1. Heavy metals in drinking water samples of Drosh and Asheriat.

	Asheriat			**Drosh**				
Parameter	Min	Max	Mean±S.D	Min	Max	Mean±S.D	WHO	USEPA
Ni ppb	0.03	**247.9**	13.84±48.8	0.02	87.27	5.08±15.20	70	-
Pb ppb	0.01	0.60	0.13±0.16	0.01	0.52	0.08±0.11	10	15
Cd ppb	0.00	0.07	0.02±0.01	0.00	0.07	0.02±0.01	3	5
Co ppb	0.01	0.21	0.05±0.05	0.01	0.34	0.06±0.08	-	-
Cr ppb	0.01	0.30	0.06±0.06	0.01	0.41	0.10±0.10	50	-
Cu ppb	0.00	0.14	0.04±0.03	0.01	0.44	0.07±0.09	2000	1000
Zn ppb	0.01	0.31	0.11±0.06	0.01	0.24	0.12±0.07	3000	5000
Mn ppb	0.01	0.34	0.08±0.08	0.01	0.41	0.10±0.09	50	50

S.D* standard deviation

Table 2. Principle component analysis for Comparison of heavy metals in water samples of Drosh.

Elements	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Ni ppb	**0.743**	0.476	-0.026	0.161	0.030
Pb ppb	**0.714**	0.060	-0.297	-0.241	-0.229
Cd ppb	-0.254	0.472	0.089	-0.102	-0.313
Co ppb	-0.433	0.379	-0.476	0.200	-0.054
Cr ppb	-0.233	0.355	-0.370	0.205	**0.596**
Cu ppb	0.178	0.492	0.484	-0.160	0.360
Zn ppb	0.393	-0.171	-0.248	**0.632**	0.165
Mn ppb	0.086	-0.015	0.335	0.323	**-0.527**
Eigen value	1.9	1.83	1.62	1.43	1.26
% Variance	14.62	14.09	12.52	11.01	9.70
Cumulative %	14.62	28.71	41.24	52.26	61.99

Table 3. Factor analysis for the selected elements in water of Asheriat.

Elements	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Ni ppb	0.290	0.173	0.340	-0.165	-0.660
Pb ppb	**0.508**	0.492	-0.005	-0.269	0.053
Cd ppb	0.200	**0.755**	-0.220	0.132	-0.146
Co ppb	-0.681	0.182	-0.385	0.321	-0.297
Cr ppb	0.458	0.439	-0.374	0.178	-0.073
Cu ppb	-0.017	-0.488	-0.555	0.279	0.174
Zn ppb	**0.538**	0.295	-0.094	0.466	**0.502**
Mn ppb	-0.308	0.154	-0.111	-0.734	0.342
Eigen value	2.47	1.89	1.73	1.61	1.19
% Variance	19.06	14.53	13.35	12.4	9.19
Cumulative %	19.06	33.60	46.95	59.35	68.54

5.3. Total/Fecal coliforms in water

Maximum probability number (MPN)/100 mL for all the water samples of Drosh and Asheriat are given in Table 4. Fifteen water samples were collected from Drosh. Among three samples (W2, W8, W22) from stream water, W2 was found within class 1 (good quality), W8 comes under class 2 (satisfactory) while W22 comes under class 3 (suspicious). Similarly, among three samples (W5, W25, W10) from Spring water, W5 was found within class 1, W25 was found within class 2 and W10 was found within class 3. However, among four samples (W28, W61, W24, W17) from groundwater, W24 and W17 were found within class 3 while W28, W61 were found within class 4 (unsatisfactory). One sample from Kabul river (W15) was found within class 3 (suspicious).

Four water samples were collected randomly from Asheriat. W41 (spring) was found within class 3 and W48 (stream) was found within class 4 (unsatisfactory). Similarly, W66 and W70 (groundwater) were found within class 4.

The above results clearly shows that no source is completely safe from biological contamination point of view in both Ashriat and Dorosh.

According to APHA (1992), water of class 1 and class 2 are safe for drinking purpose. Water of class 3 and class 4 are unfit for drinking purpose (Table 5). High probability of E.coli in drinking water indicates potential adverse health impacts on local pollution by using this water. Runoff generated from rain water may contain coliform bacteria (E.coli) associated with human and animals waste. This runoff can percolate into groundwater, which can be used as drinking water.

Table 4. Results of E.coli in water samples of Drosh and Asheriat.

Samples	Source	Location	Presemtive tests			E.coli			
			10mL	1mL	0.1mL	10mL	1mL	0.1mL	MPN/100mL
W2	Stream	Drosh	2	1	0	0	0	0	0
W5	Spring	Drosh	4	1	4	0	0	0	0
W8	Stream	Drosh	1	3	1	1	0	0	2
W10	Spring	Drosh	5	5	5	0	3	1	8
W15	Chitral River	Drosh	2	1	3	2	0	1	7
W17	Ground water	Drosh	4	5	3	1	1	1	6
W22	Stream	Drosh	5	5	5	1	3	0	8
W24	Ground water	Drosh	5	5	5	0	0	2	4
W25	Spring	Drosh	5	5	5	0	0	1	2
W28	Ground water	Drosh	5	5	5	5	5	5	1800
W41	Spring	Asheriat	5	4	1	2	2	0	9
W48	Stream	Asheriat	5	5	5	5	5	4	1600
W61	Ground water	Asheriat	5	5	5	5	5	3	900
W66	Ground water	Asheriat	5	5	5	5	5	5	1800
W70	Ground water	Asheriat	5	5	5	5	5	4	1600

Table 5. Various classes of APHA (1992) for coliform level in drinking water.

Class	**Quality**	**Coliform count/100mL**
Class 1	Excellent	0
Class 2	Satisfactory	1-3
Class 3	Suspicious	4-10
Class 4	Unsatisfactory	Greater than 10

Besides chemical pollutions, bacteriological contaminations is also the matter of utmost concern due to their potential threat to drinking water (PCRWR, 2005). Globally, different water bodies like rivers, lakes and ground aquifers in many regions are polluted due to bacteriological contaminations, mainly responsible mainly different epidemic and water-borne diseases such as diarrhea, gastroenteritis, typhoid, dysentery etc. (PCRWR, 2005; Shar et al., 2008).

A survey of micro-biological quality of natural spring water carried out by An et al. (2005) in recreational mountainous area in Seoul, South Korea, in order to assess the health risks from consumption of water by visitors. Concentrations of total coliform and Escherichia coli were investigated during summer and spring seasons in the spring's water. Escherichia coli were found in 78% of samples while total coliforms were found in all samples. The mean density of total coliforms was 228 CFU/mL and mean density of Escherichia coli was up to 15 CFU/mL. This study concluded that leaking septic systems and wildlife of the surrounding population seem to be the main source of Escherichia coli contamination which can pose serious health problems to the local people.

Afzal et al. (2000) evaluated Hudiara drain Lahore, Pakistan and in India found that fecal coliform and chemical oxygen demand (COD), total organic carbon (TOC), biological oxygen demand (BOD), pH, suspended solids (SS) and heavy metals are present in high concentration when compared with WHO guidelines. These exceeding concentration could be due to small village drains and industrial effluents. It was recommended that the drainage network can be stored in sediment reservoir. This stored water can be further used for irrigation treatment. The ground water samples of the study area are highly contaminated with E.coli. It can be associated with improper disposal of human and animal wastes which can percolates into groundwater as well as unhygienic condition and handling practices prevail in the people living in the study area.

6. Conclusion

Drinking water quality issues needs to be addressed world widely because the availability of fresh water is at threat in many parts of the world. Evaluation and periodic monitoring of drinking water is mandatory because heavy metals are toxic and bioaccumulative in nature and are capable to produce deleterious effects not only on human health but also on the overall environment. Microbial contamination is also responsible for more than 60 % of our water borne diseases. It was concluded from the present study that among trace and heavy metals in water samples, Pb, Cd, Co, Cr, Cu, and Zn, were found within the guideline values of WHO for drinking water quality and USEPA Maximum permissible limits for drinking water quality. While Ni was found above the guideline values of WHO for drinking water quality and USEPA Maximum permissible limits for drinking water quality in 8% of water samples from Drosh and 7% from Asheriat, respectively. Factor Analysis revealed that geogenic sources are mainly responsible for the possible contamination of heavy metals in the surface and groundwater of Drosh and Asheriat. On the other hand, microbiological parameter also indicates the presence of Fecal coliform in all types of sources of water in different quantities (from Suspecious to unsatisfactory). The overall results of the selected heavy metals like Ni and pathogenic parameter total coliform and E.coli suggested that water from the contaminated sites should not be used for drinking without treatment and regular monitoring and detailed evaluation on large scale is required.

Author's contribution

Seema Anjum Khattak is the lead investigator of the study and author of the manuscript who also did the data analysis. Madeeha Zaib carried out the experimental work and laboratory analysis. Liaqat ali provided the total conceptual guidance of the study in relation to geological contributions and carried out the field work, collected the samples and reviewed the manuscript.

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