International Journal of Physical Sciences Vol. 7(26), pp. 4093-5002, 5 July, 2012
Available online at http://www.academicjournals.org/IJPS
DOI: 10.5897/IJPS12.396
ISSN 1992 - 1950 ©2012 Academic Journals

Full Length Research Paper

Chemical and microbial investigation of drinking water sources from Kohat, Pakistan

Naeem Khan[1]*, Syed Tasleem Hussain[1], Javid Hussain[1], Nargis Jamila[2], Shabir Ahmed[1], Riaz Ullah[3], Zain Ullah[4], Samina Ali[1], and Abdus Saboor[1,5]

[1]Department of Chemistry, Kohat University of Science and Technology, Kohat-26000, Khyber Pakhtunkhwa, Pakistan.
[2]School of Chemical Sciences, Universiti Sains Malaysia, Penang, 11800, Malaysia.
[3]College of Engineering, Department of Chemical Engineering, King Saud University Riyadh, Saudi Arabia.
[4]Department of Chemistry, Gomal University, Dera Ismail Khan, Khyber Pakhtunkhwa, Pakistan.
[5]UNICEF, UNOCA Compound, Jalalabad Road, Kabul, 54, Afghanistan.

Accepted 13 June, 2012

Safe drinking water is one of the basic human rights and essential need for healthy life. In Pakistan, the quality of drinking water is not being managed properly and various studies provide evidence that most of the drinking-water supplies are contaminated. In this study, 60 drinking water samples from both urban and rural areas of district Kohat were analyzed chemically and microbiologically, to find out their suitability for drinking purposes. Fifty-four samples were collected from hand pumps, streams, tanks, wells and tube wells, at 15 main population zones selected. Six bottled water samples were also taken from the open market for analysis. These were investigated for various chemical parameters including sodium (Na^+), potassium (K^+), sulfate (SO_4^{2-}), phosphate (PO_4^{-3}), nitrate (NO_3^-), and nitrite (NO_2^-), using standard methods of analysis recommended by American Public Health Association (APHA). Microbiological analysis was also carried out for *Escherichia coli,* to find out any fecal contamination. The results of parameters showed variations from the WHO and Pakistan standard values for drinking water (Table 1). The K^+ and NO_2^- of 3%, SO_4^{2-} of 7%, Na^+ of 9% and NO_3^- of 16% samples were found to be higher than the WHO/Pakistan recommended values for drinking water. *E. coli* were found present in 70% of samples. From the results it was confirmed that majority of water sources are not safe to drink. Therefore, proper measures by the concerned authorities are required, to avoid health hazards.

Key words: Drinking water, Kohat, chemical, *Escherichia coli,* American Public Health Association (APHA).

INTRODUCTION

Water is one of the most important natural resources, useful for developmental purposes in both urban and rural areas (Nevondo and Cloete, 1991). Clean and safe drinking water is not only the basic need of human beings but it also has a great influence on the all aspects of life (Dara, 1997; Ahmed, 2005). Water is the most drinking fluid by living things and is the universal solvent, therefore often a potential source of causing infections. The primary concern of the people living in most of the developing countries, throughout the world is that of obtaining clean and safe drinking water. In some parts of the world, this problem is much serious by the fact that the available water sources are non potable directly, without some forms of treatment (Joyce et al., 1996).

Quality of drinking water has been debated throughout the world (Thurman et al., 1998; Leoni et al., 2005). Generally discharge of direct domestic and industrial effluent wastes, leakage from improperly maintained septic water tanks and poor management of farm wastes are considered as the major sources of water pollution and ultimately of waterborne diseases (Huttly, 1990; Jain et al., 2005). The sources of fresh water in Pakistan are glaciers, rivers and lakes but due to the shortage of rains and snowfall, and also because of pollution, Pakistan is suffering from water shortage. Presently ground water is the most abundantly (>70%) consumed valuable natural resource for various human activities (Prasad and

*Corresponding author. E-mail: nkhan812@gmail.com. Tel: +92-922-554437.

Table 1. Guidelines and standards for quality of drinking water.

Property/Parameter	Guideline/Standard values for Pakistan			WHO Standard
	Unit	HDL*	MPL**	
Sulfate as SO_4^{-2}	mg/L	200.00	400.00	250.00
Phosphate as PO_4^{-2}	mg/L	0.005	0.05	-----
Sodium as Na^{+1}	mg/L	150.00	200.00	200.00
Potassium as K^{+1}	mg/L	50.00	75.00	75.00
Nitrate as NO_3^{-1}	mg/L	45.00	45.00	45.00
Nitrite as NO_2^{-1}	mg/L	Nil	Nil	0.10
Escherichia coli	Count (mL)	0/100	0/100	0/100

*Highest desirable level; **Maximum permissible level

Narayana, 2004). Poor water quality is responsible for the deaths of an estimated five billion children annually. According to World Health Organization (WHO) survey 80% of all human diseases in developing countries are water borne (Abera et al., 2011).

Drinking water quality standards have been established by agencies such as WHO and UNICEF. In Pakistan, the Pakistan Standards and Quality Control Authority have specified the criterion for drinking-water quality. Some of the chemical parameters along with their standards specified are given in Table 1 (PCRWR, 2005; WHO, 2006).

Ground water contamination for Faisalabad, the third largest metropolis in Pakistan and well known as Manchester of Pakistan, was evaluated and the results revealed that most of the water samples were not fit for drinking purposes when compared with the standard guide lines available for drinking waters (Farid et al., 2012).

To assess microbiological safety of drinking water, indicator organisms which reside in the gastrointestinal tract of humans and animals are used in the United States and throughout the world (Anderson et al., 2005). Many studies have been carried out for a suitable indicator of fecal pollution (Jones and Roworth, 1996; Vilanova et al., 2004). Studies have shown that the occurrence of coliform group of bacteria in water sources identify the faecal contamination (Allen et al., 2000). *E. coli* are taxonomically a well defined member of the family Enterobacteriaceae. It is abundant in human and animal faeces. It may attain the high concentrations of 10^9 per gram. It is also found in sewage, treated effluents, and all other natural waters and soils which are subject to recent faecal contamination, whether from humans, wild animals, or agricultural activity. *E. coli* is widely preferred as an index of faecal contamination of drinking water sources (Fujioka et al., 1998).

In a research study on the evaluation of groundwater and surface water samples from Rohri city showed the presence of total coliform (TC), *E. coli* (EC) and heterotrophic plate count (HPC). The quality of surface water was very poor as compared to groundwater in terms of microbial content and was found to further declined after storage, indicating lack of hygiene (Abdul et al., 2010).

Kohat is a medium sized district in Khyber Pakhtunkhwa province of Pakistan. It is located at 33°35'13N 71°26'29E, with an altitude of 489 m (1607 feet) (Wikipedia, 2012). The main drinking water sources of Kohat are tube wells, wells, streams, tanks and hand pumps. Their physiochemical evaluations for pH, conductance, hardness, chloride, solids and alkalinity have shown that various sources are polluted and cannot be used for drinking purposes without treatment (Khan et al., 2012). To further confirm and strengthen these previous results, the present research is designed, to draw valuable recommendations to the concerned authorities, to solve the problem and reduce health risks.

MATERIALS AND METHODS

Sampling

A total of 60 water samples were collected from the different drinking water sources of both urban and rural areas of Kohat. It included 54 samples from 15 selected population zones and 06 bottled water from the open market. Clear, clean and dry polyethylene bottles were first rinsed with sample water at the sampling site and then filled in such a way that no air bubbles left behind in the bottles. The bottles were then placed in the refrigerator and analyzed for the various quality parameters (APHA, 1998).

Determination of chemical parameters

Sodium and potassium were determined by flame emission photometric method (3500-Na D), using Flame Photometer, Corning 410. Phosphate was analyzed by EDTA Stannous Chloride method (4500-P D). Sulfate was quantified indirectly by precipitating as barium sulfate (No = 329***), with an excess of standard barium chloride solution and titrating standard EDTA solution (APHA, 1998). Nitrate in the water samples was analyzed by using NO_3^- ion selective electrode meter, Jenway 3345, England (4500- NO_3^- D) while Nitrite was determined through colorimetric method (4500-NO_2^- B), using Hitachi U-2000 spectrophotometer (APHA, 1998).

Microbiological analysis

All water samples were analyzed for *E. coli* by multiple tube fermentation technique. Macconkey Broth, Oxoid Ltd, Basing Stoke, Hamshire, England was dissolved in distilled water and autoclaved for 15 min at 121°C. Then water samples were mixed and incubated at 44°C, for 24 h. The change of color from bluish to white indicated the presence of *E. coli* (Lenore et al., 1998).

RESULTS AND DISCUSSION

Sodium in water samples

The concentration of sodium in all water samples varied in the range of 10.5 to 875.0 mg/L, the lowest being observed in Wah bottled water while the highest in Lachi hand pump. The Na content values from hand pumps, streams, tanks, tube wells and wells varied in the range of 17.3 to 875.0 mg/L, 15.6 to 151.2 mg/L, 18.5 to 140 mg/L, 21.4 to 595.9 mg/L and 13.8 to 415.0 mg/L respectively. Bottled waters showed the Na content values ranging from 10.5 to 20.2 mg/L. The Na content values of 05 samples were found higher than the WHO (200 mg/L) and Pakistan (150 to 200 mg/L) standards for drinking water. These polluted samples include Lachi hand pump (875.0 mg/L) and tube well (595.9 mg/L), Ara Khel tube well (211.7 mg/L) and well (415.0 mg/L) and Shakadarra hand pump (342.3 mg/L) (Table 2 and Figure 1). These results obtained are supported by the published literature by Farid et al. (2012) and Khan et al. (2008).

Water from sources with high concentration of Na, especially when it is above 300 mg/L, is harmful when used for drinking purposes. The acute effects include nausea, vomiting, convulsions, muscular twitching and rigidity, and cerebral and pulmonary edema. Several studies have suggested that high levels of sodium in drinking water are responsible for the increased blood pressure. Other researchers have also shown a direct link between high sodium intake and hypertension (WHO, 1996).

Potassium in water samples

The concentration of potassium in all water samples analyzed were found in the range of 0.0 to 492.5 mg/L, the lowest being observed in Nestles bottled water while the highest in Lachi hand pump. The K content values of 02 samples, Lachi hand pump (492.5 mg/L) and tube well (484.5 mg/L), were found high than the WHO (200 mg/L) and Pakistan (150 to 200 mg/L) standards for drinking water (Table 2 and Figure 2). These results are in agreement with literature (Farid et al., 2012; Khan et al., 2008).

Potassium does not cause intoxication, because it is excreted by healthy kidneys rapidly and also because large doses cause vomiting. However, after acute ingestion of potassium in greater than 5.5 g for a 70 kg adult, by individuals with normal kidney function overwhelm homeostatic mechanisms and cause death (Buckley et al., 1995).

Phosphate in water samples

The concentration of phosphate in all water samples varied in the range of 0.0 to 1.6 mg/L, the lowest being observed in Nestle bottled water while the highest in Shaikhan hand pump. The PO_4^{3-} content values of water from hand pumps, streams, tanks, tube wells and wells varied between 0.0 and 0.102, 0.072, 0.201, 0.076 and 0.428 mg/L, respectively. Bottled waters showed the PO_4^{3-} content values ranging from 0.00 to 0.026 mg/L (Table 2 and Figure 3). These results are supported by published literature (Khan et al., 2008). Phosphates are not very much toxic to people or animals unless they are present in extremely high levels. Digestive problems occur from extremely high levels of phosphates in drinking water sources. The orthophosphate cause bone decalcification and very importantly increased parathyroid gland activity. This is due to the regulation of the calcium phosphorus balance in the human body by orthophosphates (Weiner et al., 2001).

Sulfate in water samples

The concentration of sulfate in all water samples varied in the range of 38.5 to 483.84 mg/L, the lowest being observed in Nestle bottled water while the highest in Lachi hand pump. The SO_4^{-2} content values of 04 samples were found high than the WHO (250 mg/L) standard. Only two samples were found to have high concentration of SO_4^{-2} than Pakistan (200 to 400 mg/L) standard for drinking water. The polluted samples according to Pakistan standards include Lachi hand pump (483.84 mg/L) and tube well (403.2 mg/L) (Table 2 and Figure 4). The results obtained are high as compared to the previous study (Khan et al., 2008). This may be due to the increase in population in the recent years.

The major physiological effects resulting from the ingestion of large quantities of sulfate are catharsis and gastrointestinal irritation. The presence of sulfate in drinking water also results in a noticeable taste. Taste threshold concentrations for various sulfate salts is above 500 mg/L for the general population, but sensitive individuals may find the taste objectionable at lower sulfate concentrations (Schifmann et al., 2001).

Nitrate in water samples

The concentration of nitrate in all water samples analyzed were found in the range of 12.57 to 541.94 mg/L, the

Table 2. Values of chemical parameters investigated (mg/L).

Study area	Source	Sodium	Potassium	Phosphate	Sulfate	Nitrate	Nitrite
Hasan Abad Shahpur	Hand pump	88.0	1.5	0.96	103.7	26.7	BDL
	Tube well	61.5	2.9	0.56	84.5	22.9	BDL
	Well	93.0	2.3	0.60	138.2	23.5	0.428
Jungle Khail	Stream	53.5	2.7	0.70	69.1	28.2	0.061
	Tank	39.0	2.9	0.78	73.0	22.8	0.020
	Tube well	70.0	2.7	0.64	115.2	37.5	BDL
KDA	Hand pump	30.0	1.8	0.56	164.0	32.7	0.102
	Tank	18.5	1.3	0.60	138.0	19.0	BDL
	Tube well	26.6	1.4	0.67	160.0	23.5	0.074
Myana	Hand pump	34.0	4.3	1.03	164.0	41.5	0.063
	Stream	20.0	1.3	0.72	118.0	18.4	BDL
	Tank	30.2	3.9	0.83	158.0	37.2	0.108
	Tube well	32.0	3.6	0.44	143.0	34.0	0.076
Ali Zai	Hand pump	17.3	1.7	0.52	138.0	18.5	BDL
	Stream	20.5	2.6	0.49	130.0	17.6	BDL
	Tank	28.0	2.0	0.65	142.0	22.3	BDL
	Tube well	21.4	2.4	0.48	136.0	26.0	0.038
	Well	25.2	2.7	0.55	145.0	32.7	0.044
Muhammad Zai	Hand pump	18.9	3.8	0.58	140.0	34.1	0.042
	Stream	34.2	3.7	0.56	211.0	28.6	0.038
	Tank	46.2	3.9	0.76	170.0	26.6	BDL
	Tube well	44.1	4.2	0.57	182.0	41.1	0.034
Uster Zai	Hand pump	115.0	12.5	0.56	261.1	123.8	0.024
	Stream	15.6	2.7	0.64	88.3	15.6	BDL
	Tank	80.6	3.3	0.94	119.1	13.4	BDL
	Tube well	22.6	5.1	0.58	49.9	22.2	BDL
	Well	13.8	2.9	0.68	23.1	16.3	BDL
College Town	Hand pump	32.0	2.3	0.82	124.0	34.0	0.061
	Tank	67.5	4.4	0.56	84.5	32.9	BDL
	Tube well	80.5	3.2	0.62	72.4	28.4	BDL
Shaikhan	Hand pump	66.6	2.2	0.70	57.6	25.6	0.043
	Tank	52.2	3.3	1.60	96.0	44.2	BDL
	Tube well	59.4	3.5	0.74	111.4	65.4	0.021
Belitang	Hand pump	83.7	3.6	0.04	215.1	22.8	BDL
	Tank	70.2	3.3	0.64	145.9	16.5	0.053
	Tube well	93.6	4.2	0.60	172.8	21.6	BDL
	Well	104.0	4.6	0.80	192.4	44.2	0.068
Gumbat	Hand pump	98.0	2.6	1.24	156.0	38.4	0.082
	Tank	104.0	3.0	0.92	178.0	28.6	0.056
	Tube well	86.0	3.8	0.58	132.0	41.3	0.068
	Well	110.0	4.2	0.64	172.0	38.1	0.074

Table 2. Contd.

Dara Adam Khail	Hand pump	41.0	1.98	0.92	112.0	36.1	0.054
	Tank	40.0	2.5	0.54	80.6	30.3	BDL
	Tube well	54.0	4.2	0.64	110.0	41.5	BDL
Ara Khail	Tank	46.0	3.2	1.32	114.0	46.0	0.201
	Tube well	11.7	1.3	0.98	65.3	58.8	0.102
	Well	415.0	5.2	1.44	234.3	541.9	0.073
Lachi	Hand pump	875.0	492.5	0.94	483.8	477.8	BDL
	Tank	140.0	9.8	1.00	134.4	20.0	BDL
	Tube well	595.9	484.5	1.14	403.2	494.5	0.021
Shakadara	Hand pump	342.3	3.7	1.42	230.0	60.4	0.086
	Stream	151.2	6.4	0.83	260.0	45.9	0.072
	Tank	138.0	4.7	0.65	210.0	55.0	0.064
	Tube well	126.0	1.3	0.60	132.0	51.3	0.060
Bottle water	Nestle	12.9	0.0	0.00	38.4	22.4	BDL
	Wah	10.5	1.7	0.02	153.6	18.5	BDL
	Country	16.1	2.0	0.00	42.3	12.6	BDL
	Mitchell's	20.2	5.7	0.00	92.2	20.2	0.026
	Kinza	17.5	1.2	0.04	47.7	27.3	BDL
	Aqua	15.1	0.7	0.00	57.6	14.7	BDL

BDL = Below determination limit.

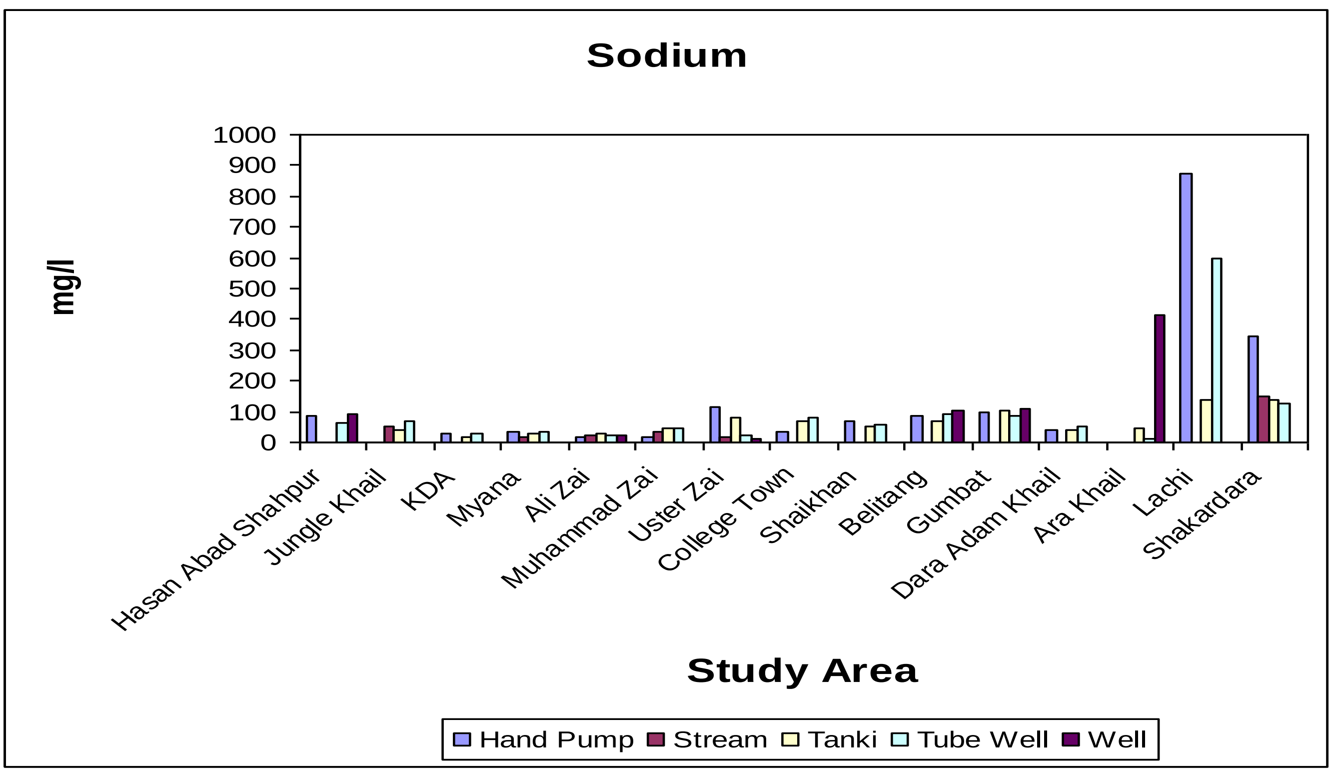

Figure 1. Sodium in water samples.

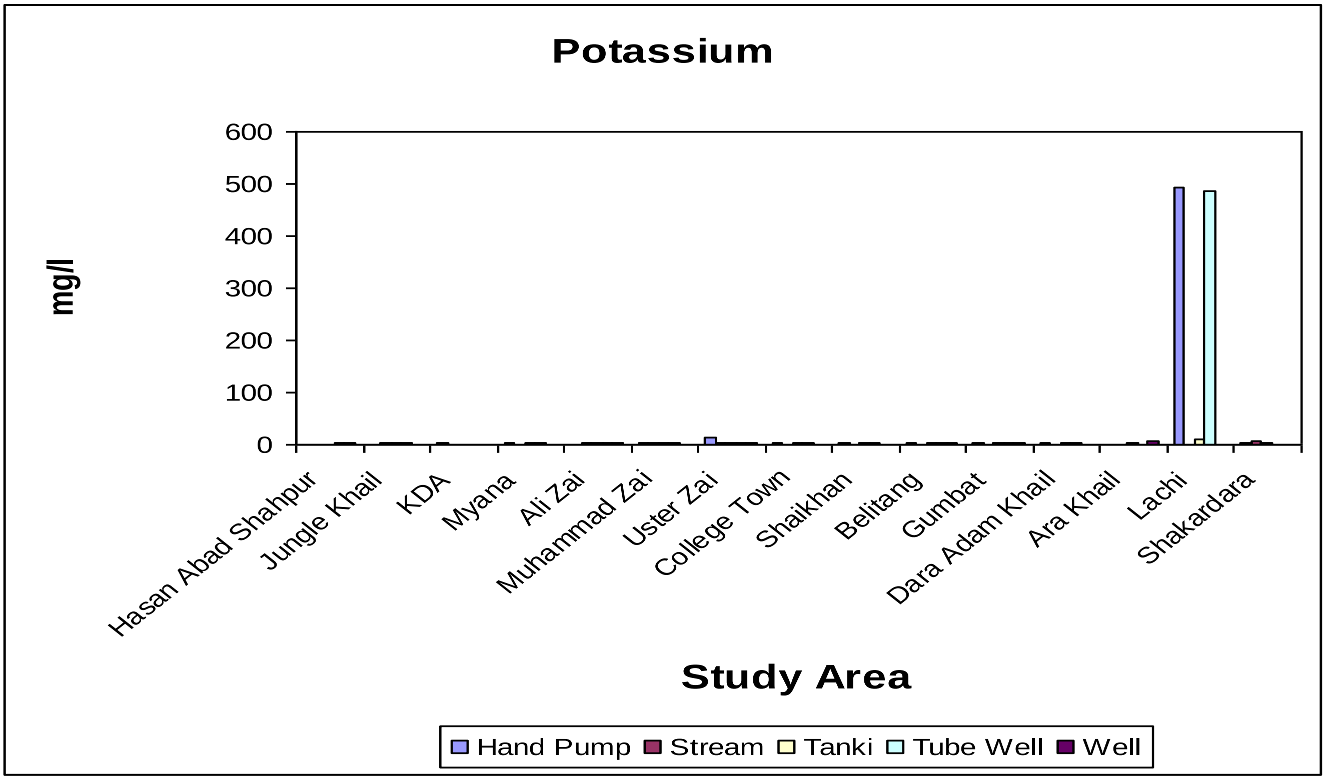

Figure 2. Potassium in water samples.

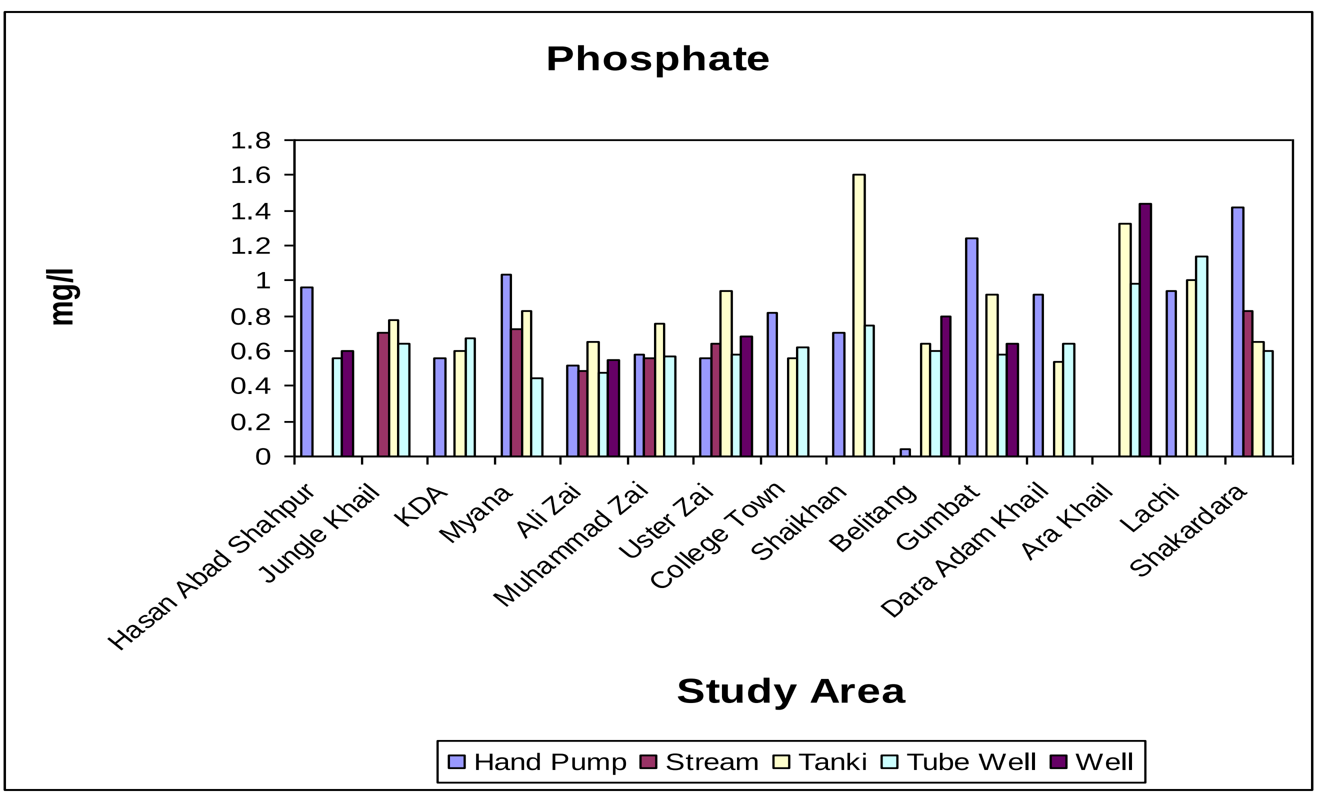

Figure 3. Phosphate in water samples.

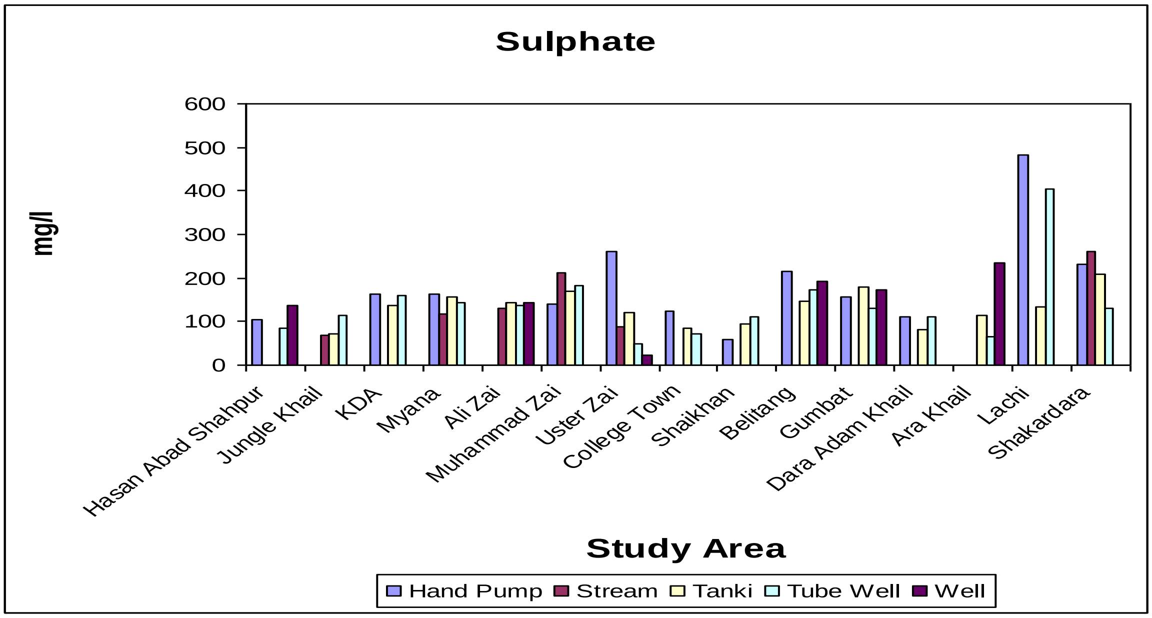

Figure 4. Sulfate in water samples.

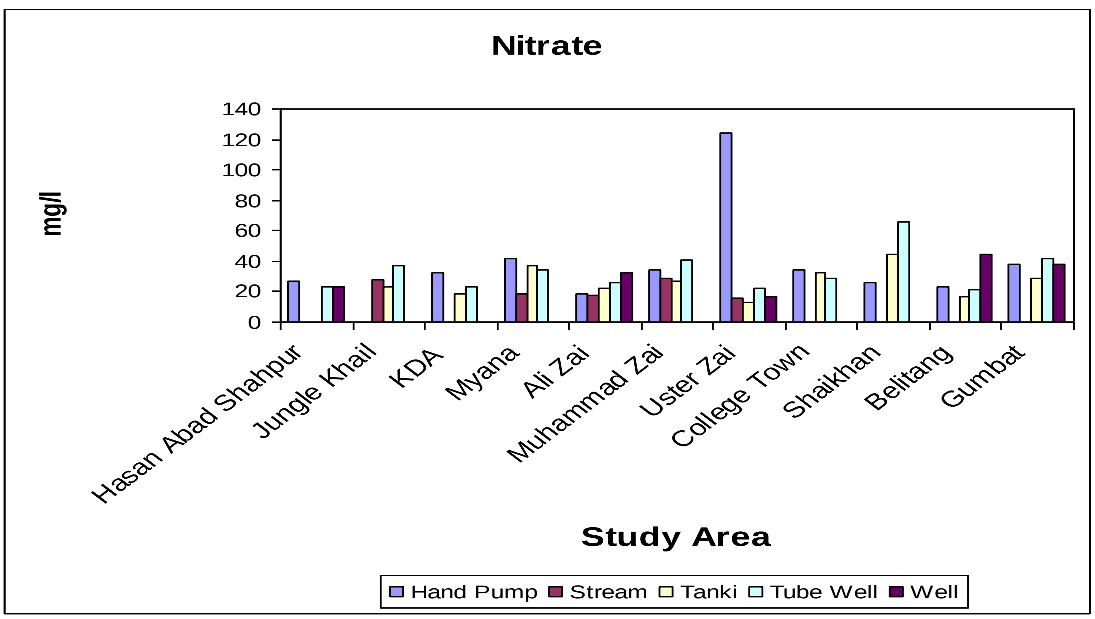

Figure 5. Nitrate in water samples.

lowest being observed in Country bottled water while the highest in Arakhel well. The NO_3^- content values of water from hand pumps, streams, tanks, tube wells and wells varied in the range of 18.46 to 477.8 mg/L, 15.62 to 45.88 mg/L, 13.44 to 55.0 mg/L, 21.57 to 494.50 mg/L and 16.27 to 541.94 mg/L respectively. Bottled water showed the NO_3^-content values ranging from 10.5 to 27.32 mg/L. The NO_3^- content values of 09 samples were found to be higher than the WHO (45.0 mg/L) and Pakistan (45.0 mg/L) standards for drinking water. Among the 09 polluted samples 06 are those with NO_3^- concentration less than 70.0 mg/L. The other 03 highly polluted samples include Lachi hand pump (477.8 mg/L) and tube well (494.5 mg/L) and Arakhel well (541.9 mg/L) (Table 2 and Figure 5). The polluted water sources are not recommended for drinking purposes (Sigler and

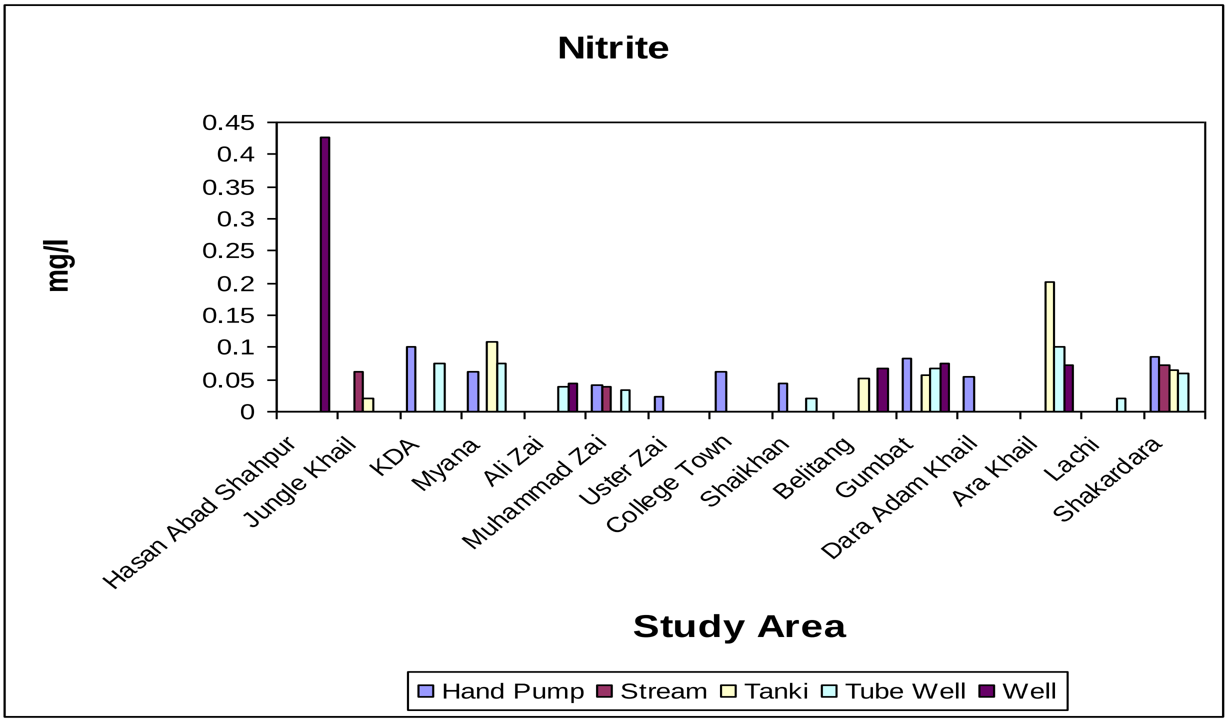

Figure 6. Nitrite in water samples.

Table 3. *Escherichia coli* in water samples (/100 mL).

Study area	Hand pump	Stream	Tank	Tube well	Well
Hasan Abad Shahpur	NC	NA	NA	NC	C
Jungle Khail	NA	NC	C	C	NA
KDA	NC	NA	C	NC	NA
Myana	C	C	C	NC	NA
Ali Zai	C	C	C	C	C
Muhammad Zai	C	C	C	NC	NA
Uster Zai	C	C	C	NC	C
College Town	C	NA	C	NC	NA
Shaikhan	C	NA	C	NC	NA
Belitang	C	NA	C	C	C
Gumbat	NC	NA	C	NC	C
Dara Adam Khail	C	NA	C	NC	NA
Ara Khail	NA	NA	C	NC	C
Lachi	C	NA	NC	C	NA
Shakadara	C	C	C	NC	NA

Bottled water	Nestle	Wah	Country	Mitchell's	Kinza	Aqua
	NC	NC	NC	NC	NC	NC

NC = Non contaminated, C = Contaminated, NA = Not available.

Montana, 2012).

Excessive concentrations of nitrate can be harmful to humans and wildlife. Nitrate is broken down in our intestines to become nitrite. Nitrite reacts with hemoglobin in human blood to produce methemoglobin, which limits the ability of red blood cells to carry oxygen.

This condition is called methemoglobinemia or blue baby syndrome (NAS, 1995).

Nitrite in water samples

The concentration of Nitrite in all water samples varied in the range of 0.00 to 0.428 mg/L. Among total 60 samples, 27 were having NO_2^- concentration below the determination limit (BDL) and are therefore very safe. Two samples showed high concentration of NO_2^- than the WHO (0.10 mg/L) standard for drinking water. These include Hassan Abad well (0.428 mg/L) and Ara Khel tank (0.201) (Table 2 and Figure 6).

The polluted samples are not recommended for drinking purposes (Sigler and Montana, 2012). NO_2^- is poisonous and therefore water from the polluted sources is very harmful because of its ability to produce methemoglobinemia. This disease may cause death (NAS, 1995).

E. coli in water samples

Water samples were examined for the presence of *E. coli* in order to find out any fecal contamination in the various drinking water sources. The results showed that 38 samples out of 60 are contaminated with *E. coli*. From 15 tube wells, 11 were non contaminated and only 04 were contaminated with *E. coli*. Among hand pumps, tank and streams 13 out of 14, 14 out of 15, and 05 out of 06 were found contaminated with *E. coli* respectively. All the 06 wells were found contaminated while all 06 bottled water were non contaminated with *E. coli* (Table 3). These results are in agreement with previous findings (Abdul et al., 2010; Abera et al., 2011).

Coliform bacteria, such as *E. coli*, are dangerously infectious organisms which can cause various serious infections in human beings. It was this type of coliform which caused the infamous Jack in the Box hamburger poisoning incidents in 1999, in which four children were killed and 700 sickened (Swerdlow et al., 1992). Thus in terms of this microbiological study it can be said that bottled water and comparatively tube wells are the safe sources of drinking water.

Conclusion

Drinking water sources of Kohat are mostly polluted and their use may cause various health hazards. Among the various sources, tube wells are comparatively safe for human consumption. Lachi, Shakardara and Arakhail are the highly polluted areas where drinking water needs treatment before usage.

ACKNOWLEDGEMENT

This research was financially supported by the Higher Education Commission (HEC), Islamabad, Pakistan.

REFERENCES

Abdul HS, Yasmeen FK, Nisar AK, Irshad HS, Syed MZ, Pir BG (2010). Drinking water quality in Rohri city, Sindh, Pakistan. Afr. J. Biotechnol., 9(42): 7102-7107.

Abera S, Zeyinudin A, Kebede B, Deribew A, Ali S, Zemene E (2011). Bacteriological analysis of drinking water source. Afr. J. Microbiol. Res., 5(18): 2638-2641.

Ahmed R (2005). Studies on the chemistry control of some selected drinking and industrial waters. Pak. J. Sci. Ind. Res., 48(3): 174-179.

Allen MJ, Clancy JL, Rice EW (2000). Pathogen monitoring of old baggage from the last millennium. J. Am. Water Works Assoc., 92(9): 64-76.

Anderson LK, John EW, Valcric JH (2005). Persistence and differential survival of fecal indicator bacteria in subtropical waters and sediments. J. Appl. Environ. Microbiol., 71: 3041-3048.

APHA (1998). American Public Health Association. Standard methods for the examination of water and wastewater. 20th Ed. USA.

Buckley NA, Dawson AH, Reith DA (1995). Controlled release drugs in overdose clinical considerations. Drug Safety, 12 (1): 73-84.

Dara SS (1997). A textbook of environmental chemistry and pollution control, Chand Publishing Company, New Delhi, India.

Farid S, Baloch MK, Ahmed SA (2012). Water pollution: Major issue in urban areas. Int. J. Water Res. Environ. Eng., 4(3): 55-65.

Fujioka R, Sian-Denton C, Borja M, Castro J, Morphew K (1998). Soil: the environmental source of *Escherichia coli* and Enterococci in Guamas streams. J. Appl. Microbiol., 85: Suppl 1:83S-89S.

Huttly SR (1990). The impact of inadequate sanitary condition on health. In developing countries. World Health Stat. Q., 43: 118-126.

Jain P, Sharma JD, Sohu D, Sharma P (2005). Chemical analysis of drinking water of villages of sanganer Tehsil, Jaipur district. Int. J. Environ. Sci. Technol., 2(4): 373-379.

Jones IG, Roworth M (1996). An outbreak of *Escherichia coli* 0157 and campylobacteriosis associated with contamination of drinking water supply. Soc. Public Health, 110: 277-282.

Joyce TM, Meguigan KG, Elmore-Meegan M, Conroy RM (1996). Inactivation of fecal bacteria in drinking water by solar heating. J. Appl. Environ. Microbiol., 62: 399-402.

Khan H, Haider S, Saeed K, Ali N (2008). Assesment of potable water quality of Kohat division and its impact on health. J. Chem. Soc. Pak., 30(2).

Khan N, Hussain TS, Hussain J, Jamila N, Ahmed S, Ullah R, Ullah Z (2012). Physiochemical Evaluation of the Drinking Water Sources of District Kohat, Khyber Pakhtunkhwa, Pakistan. Afr. J. Pharm. Phamacol. (Accepted for Publication).

Lenore SC, Arnold EG, Andrew DE (1998). Standard Methods for Examination of Water and Wastewater. American Public Health Association. American Water Works Association and World Environment Federation. 20th Edition, Washington DC.

Leoni EGD, Legnani PP, Sacchetti R, Spampi S, Zanetti F (2005). Legionella waterline colonization: detection of *Legionella* species in Legionella waterline colonization: detection. J. Appl. Microbiol., 98: 373-379.

NAS, National Research Council (1995). Nitrate and Nitrite in Drinking Water. Available online at; www.nap.edu/catalog/9038.html.

Nevondo VS, Cloete ST (1991). Reclamation of Ponds, Lakes, and Steams with Fish Toxicant. A review of Food and Agriculture Organization of the United Nations, FAO, FISH Tech, Pap, 100: 57-61.

PCRWR (2005). Pakistan Council of Research in Water Resources. Islamabad, Pakistan. Workshop to Finalize National Drinking Water Quality Standards, 01-04 March, 2005, Health Services Academy, Ministry of Health, Pakistan, 2005. Available online at; (http://www.pcrwr.gov.pk/wq_phase2_report/chapter_no. 3.pdf).

Prasad BG, Narayana TS (2004). Subsurface water quality of different sampling stations with some selected parameters at Machilipatnam town. Nat. Environ. Pollut. Technol., 3(1): 47-50.

Schiffmann SS, Bennett JL, Raymer JH (2001). Quantification of Odours and Odourants from Swine Operations in North Carolina. Agric. Forest Meteorol., 108: 213-240.

Sigler WA, Montana JB (2012). Nitrate and nitrite fact sheet. Montana State University Extension Water Quality Program. Department of Land Resources and Environmental Sciences. USA. Available online at:http://waterquality.montana.edu/docs/homeowners/nitrate_fact_sheet.pdf.

Swerdlow DL, Woodruff BA, Brady RC, Griffin PM, Tippen S, Donnel HD, Geldreich E, Payne BJ, Meyer A, Wells JG, Greene KD (1992). A waterborne outbreak in missouri of *Escherichia coli* O157:H7 associated with bloody diarrhea and death. Ann. Intern Med., 117(10): 812- 819.

Thurman R, Faulkner B, Veal D, Cramer G, Meiklejohn M (1998). Water quality in rural Australia. J. Appl. Microbiol., 84(4): 627-632.

Vilanova X, Mancro A, Ccrda-Cucllar M, Blanch AR (2004). The composition and persistence of fecal coliform and enterococal population in sewage treatment plant. J. Appl. Microbiol., 96: 279-288.

Weiner M L, Salminen WF, Larson PR, Barter RA, Kranetz JL, Simon GS (2001). Toxicological review of inorganic phosphates. Food Chem. Toxicol., 39(8):759-786.

WHO (1996). World Health Organization. Guidelines for drinking-water quality, health criteria and other supporting information., 2nd Edn., Geneva.

WHO (2006). World Health Organization. Guidelines for Drinking-water Quality, First addendum to 2nd Edn, Recommendations, 1, 2006.

Wikipedia (2012). Wikipedia, the free encyclopedia. Kohat Pakistan page. Available online at: http://www.fallingrain.com/world/PK/03/Kohat.html.