Physiochemical investigation of drinking water sources from Tehsil Lachi, Kohat

Naeem Khan[1,2]*, Syed Tasleem Hussain[1], Asif Khan[1], Kyong Su Kim[2]

[1] Department of Chemistry, Kohat University of Science & Technology, Kohat-26000, Khyber Pakhtunkhwa, Pakistan
[2] Department of Food and Nutrition, Chosun University, Dong-gu, Gwangju, 501-759, Republic of Korea
*Corresponding author: Naeem Khan
Department of Chemistry
Kohat University of Science & Technology (KUST), Kohat-26000,
Khyber Pakhtunkhwa, Pakistan.
Email: nkhan812@gmail.com
Phone: +92-333-9302834

Abstract

Water is one of the most precious commodities of life and society. Clean and safe drinking water is the basic need of human beings. In this study a total of 22 drinking water samples, from the various sources of Tehsil Lachi, were analyzed physiochemically, to find out their suitability for drinking purposes. Nineteen samples were collected from hand pumps, streams, tanks, wells and tube wells, at 04 main population zones namely Lachi town, Sudal, Malgin and Darmalak. In addition 03 commonly consumed bottled water samples, Aquafina, Nestle and Kinley, were also taken from the open market. These were investigated for 15 different physiochemical parameters including pH, electrical conductance (EC), total solids (TS), total dissolved solids (TDS), total suspended solids (TSS), alkalinity, total hardness, calcium hardness, magnesium hardness, chloride (Cl), sodium (Na), potassium (K), arsenic (As), lead (Pb), and selenium (Se), using standard methods of analysis recommended by American Public Health Association (APHA). The results showed that except pH, alkalinity and potassium all other physiochemical parameters were not in the permissible limits of WHO and Pakistan, for drinking water. This study showed that the drinking water quality of Tehsil, Lachi, is worse and it needs necessary treatment before consumption.

Keywords: drinking water, physiochemical, APHA, Lachi

{**Citation:** Naeem Khan, Syed Tasleem Hussain, Asif Khan. Physiochemical investigation of drinking water sources from Tehsil Lachi, Kohat. American Journal of Research Communication, 2013, 1(5):170-190} www.usa-journals.com, ISSN:2325-4076.

Introduction

Water is one of the most important natural resources, useful for developmental purposes in both urban and rural areas (1). 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 (2-3). 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 harder by the fact that many of the available water sources are non potable directly, without some forms of treatment (4).

Quality of drinking water has been debated throughout the world (5-6). 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 (7-8). 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. To overcome this situation, there is a need to use ground water. Presently ground water is the most abundantly (>70 %) consumed valuable natural resource for various human activities (9). 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 (10).

Drinking water quality deterioration is a serious issue in several parts of the world. Various researchers have shown that drinking water in many countries does not meet WHO standards 11-13). Water quality in Pakistan is also not in accordance to the WHO/Pakistan guidelines for drinking water. It is deteriorating mainly as a result of disposal of the municipal and industrial

wastewaters and also because of the saline drainage flow from agricultural areas (14-15). The past research studies have shown that various quality parameters of Pakistan drinking water are not in accordance to the WHO/Pakistan standards (15-22). Polluted drinking water causes outbreak of diseases. Recently in three districts of Sind province, namely Thatta, Badin, and Thar, poor water quality was found responsible for gastroenteritis, diarrhea and vomiting, kidney, and skin problems (23).

The main drinking water sources of Kohat are tube wells, wells, streams, tanks and hand pumps. Their physiochemical evaluations showed that Ara Khail, Lachi and Shakar dara are the most polluted areas where most of the drinking water sources exceed WHO/Pakistan standards for drinking water (21). The present work is designed specifically on Tehsil Lachi, as a continuation of our previous work to further confirm and strengthen our previous results on drinking water pollution and draw valuable recommendations to the concerned authorities, to solve the problem.

Materials and Methods

Sampling

A total of 22 samples were collected from various drinking water sources of Tehsil Lachi, district Kohat. It included 19 samples from wells, tube wells, tanks, streams and hand pumps, of the 04 selected population zones and 03 commonly consumed bottle water from the open market. Clear, clean and dry polyethylene bottles of 1 L and 100 mL capacity were used. First the bottles were 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 placed in refrigerator and analyzed for various quality parameters. The 1 L bottles were used for physiochemical analysis while the 100 mL sample bottles were used for heavy metals (24).

Determination of physical parameters

pH was measured by electrometric method, using pH meter, Mettler Delta 320, England, while electrical conductivity was determined by laboratory method, using conductivity meter, Jenway 4060, England (24).

Total solids were measured by drying the samples in oven, Memmert B 54, Schwabach W. Germany, at 103-105 ºC. The increase in weight was expressed as mg of total solids per liter of sample. For total dissolved solids, well mixed sample was filtered through Beckman filter paper and dried in oven at 103-105 ºC. The total suspended solids were calculated from the difference between total solids and total dissolved solids (24).

Determination of chemical parameters

Alkalinity was determined in water samples by titration method, using methyl orange indicator and standardized sulfuric acid solution (24). Total hardness was determined as mg $CaCO_3$/L, by EDTA titrimetric method, using eriochrome black-T indicator and standard solution of ethylenediamminetetraacetic acid (EDTA). Calcium hardness was measured by EDTA titrimetric method, using murexide indicator and standard EDTA solution. Magnesium hardness was calculated from the difference between the total hardness and calcium hardness (24).

Chloride was determined by argentometric method, using potassium chromate indicator and standard $AgNO_3$ solution. Sodium and Potassium were determined by flame emission photometric method, using Flame Photometer**,** Corning 410, Germany (24).

Determination of heavy metals

The concentration of lead, selenium and arsenic in all water samples were determined by using atomic absorption spectrophotometer, Perkin Elmer, Model 3100, after properly calibrating the instrument with standards for precised results (24).

Results and discussion

Physical parameters

pH of water samples analyzed ranged from 6.79 to 8.02. The lowest value was found in Malgin stream and the highest was in Sudal stream. Bottled water was having pH from 7.22 to 7.55 (Table 2, Figure 1). Thus all water samples have pH within the permissible limits of WHO and Pakistan Standards (6.5 – 8.5) for drinking water (Table 1) (25-29).

Table 1. Guidelines and standards for quality of drinking water

S. #	GUIDELINE/STANDARD VALUES FOR PAKISTAN				WHO STANDARDS
	Properties/Parameters	Unit	HDL*	MPL**	
1.	pH	---	7.0-8.5	6.5-9.2	6.5-9.2
2.	Electrical Conductance	$\mu S/cm^3$	1000.00	1200.00	1200.00
3.	Total Solids	mg/L	1000.00	1500.00	1000.00
4.	Total Dissolved Solids	mg/L	1000.00	1500.00	995.00
5.	Total Suspended Solids	mg/L	05.00	05.00	05.00
6.	Total Hardness as $CaCO_3$	mg/L	200.00	500.00	500.00
7.	Calcium Hardness as $CaCO_3$	mg/L	75.00	200.00	250.00
8.	Magnesium Hardness as $CaCO_3$	mg/L	30.00	150.00	150.00
9.	Total Alkalinity as $CaCO_3$	mg/L	400.00	500.00	500.00
10.	Chloride as Cl^{-1}	mg/L	200.00	600.00	250.00
11.	Sodium (Na)	mg/L	150.00	200.00	200.00
12.	Potassium (K)	mg/L	50.00	75.00	75.00
13.	Lead (Pb)	mg/L	0.01	0.05	0.01
14.	Selenium (Se)	mg/L	0.01	0.01	0.01
15.	Arsenic (As)	mg/L	0.01	0.05	0.01

* Highest Desirable Level ** Maximum Permissible Level

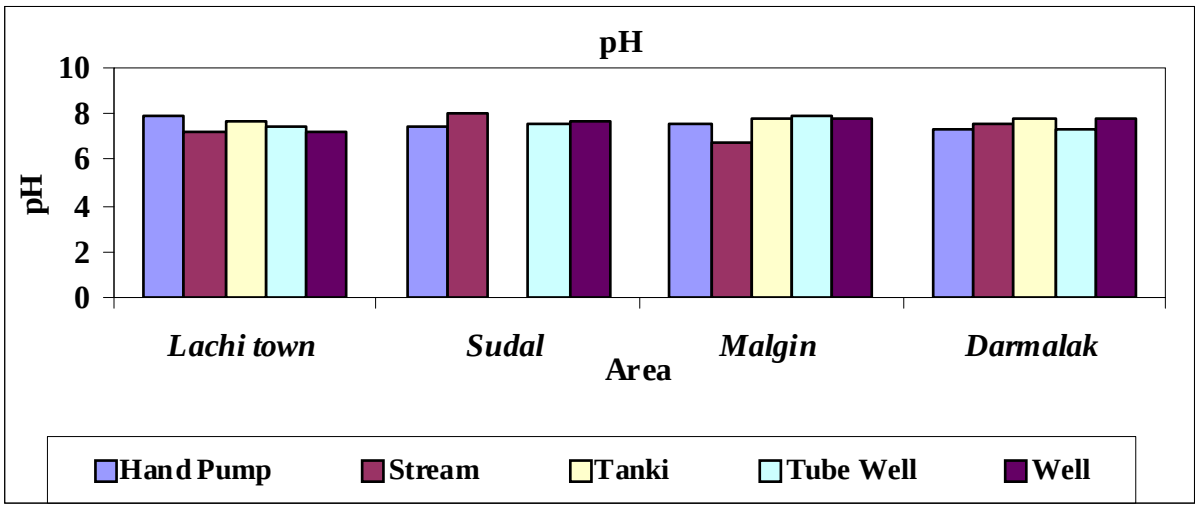

Figure 1. pH values of water samples.

Table 2. Physical Parameters

Area	Source	pH	Conductance ($\mu S/cm^3$)	Solids (mg/L)		
				TS	TDS	TSS
Darmalak	Hand pump	7.27	2701	4073	3940	133
	Stream	7.52	784	807	787	20
	Tank	7.82	846	887	840	47
	Tube well	7.32	602	680	647	33
	Well	7.83	1355	1567	1460	107
Lachi town	Hand pump	7.90	932	967	927	40
	Stream	7.21	2850	4193	4067	126
	Tank	7.67	780	847	800	47
	Tube well	7.45	1575	1960	1887	73
	Well	7.20	3025	4320	4147	173
Malgin	Hand pump	7.54	1651	2293	2047	246
	Stream	6.79	308	1680	1780	80
	Tank	7.78	1510	1760	1533	227
	Tube well	7.94	1634	1893	1747	146
	Well	7.74	1336	1467	1293	174
Sudal	Hand pump	7.37	2813	4047	3893	154
	Stream	8.02	1355	1453	1280	173
	Tube well	7.55	1221	1433	1393	40
	Well	7.64	947	967	827	140
Bottle Water	Aquafina	7.25	133	253	207	46
	Kinley	7.55	277	333	287	46
	Nestle	7.34	377	467	407	60

Electrical conductivity values of 10 samples (45.45 %) were within the permissible limits (1200 $\mu S/cm^3$) for drinking purposes. The highly polluted sources with electrical conductance values above 2000 $\mu S/cm^3$ were Darmalak hand pump (2701 $\mu S/cm^3$), Sudal hand pump (2813 $\mu S/cm^3$), Lachi town stream (2850 $\mu S/cm^3$) and well (3025 $\mu S/cm^3$) (Table 2, Figure 2). In Malgin 4 sources out of 5, Sudal 3 out of 4, Lachi town 3 out of 5 and Darmalak 2 out of 5 are having high values of electrical conductance than the permissible range. Electrical conductivity does not have a direct health effect; however, it shows the concentration of the dissolved minerals in water. The high values of conductivity obtained may be due to high concentrations of sodium ions, chloride ions along with other dissolved ions present in the water (24, 30).

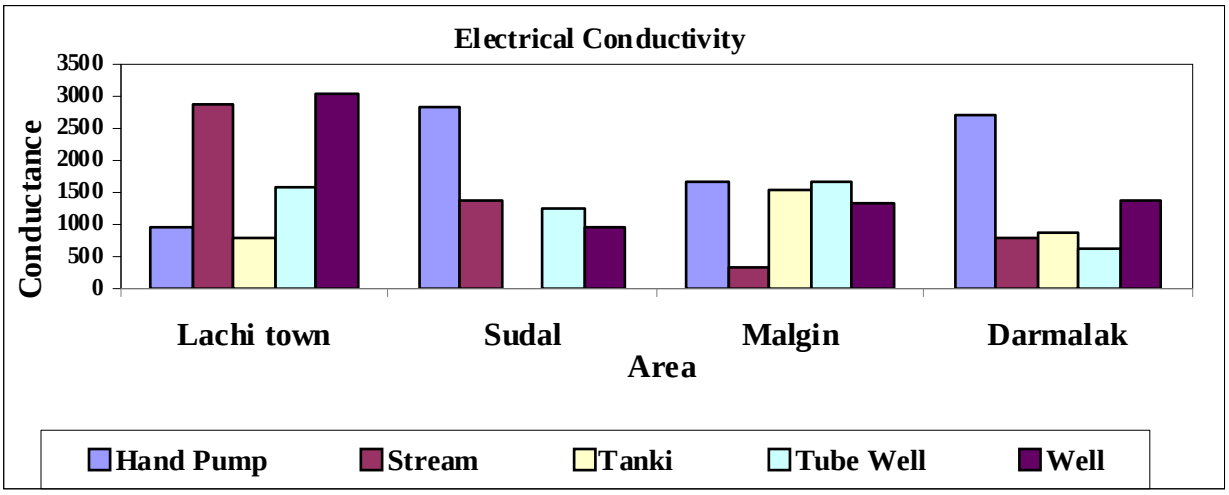

Figure 2. Electrical Conductance of water samples

Solids (TS, TDS and TSS) in 9 samples (41%) were found within the permissible limits of WHO/Pakistan (Table 1, Figure3-5), while 13 (59%) were with high values. The minimum value of solids was found in Aquafina (253 mg/L) and maximum in Lachi well (4320 mg/L) (Table 2, Figure 3, 4 &5). The results of TS, TDS and TSS are in accordance to Khan et al; 2012b (21). Solids indicate the presence of various dissolved and suspended substances in water. It adversely affects water quality by inducing objectionable taste, affecting light penetration. Higher concentrations of solids usually pose no health threat to humans until the values exceed 10,000 mg/L (24, 31).

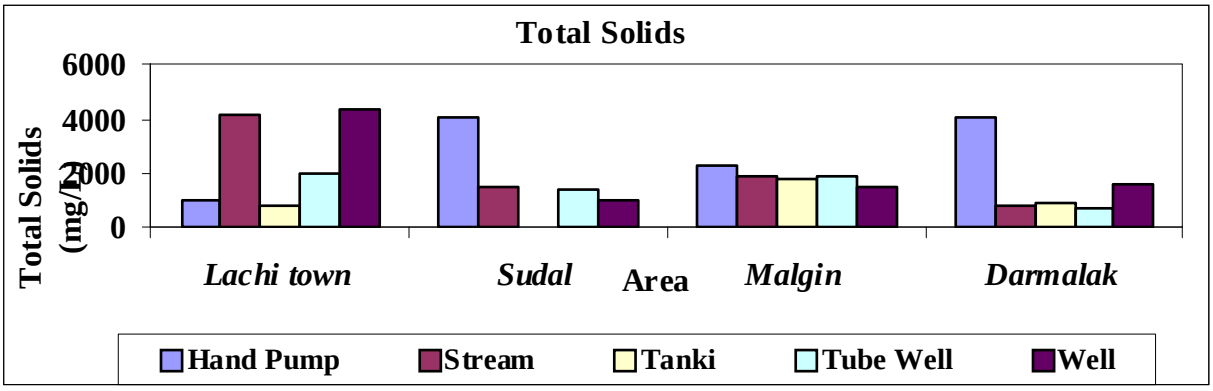

Figure 3. Total Solids in water samples

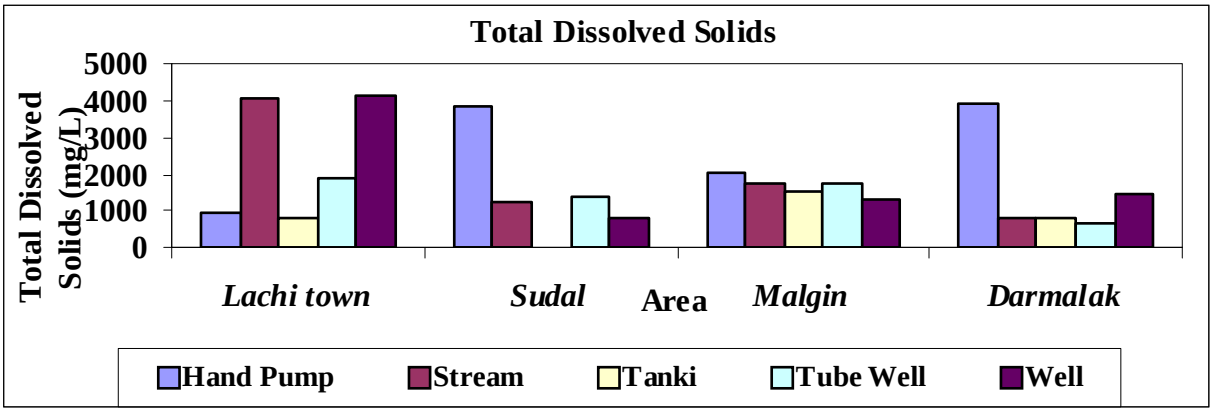

Figure 4. Total dissolved solids

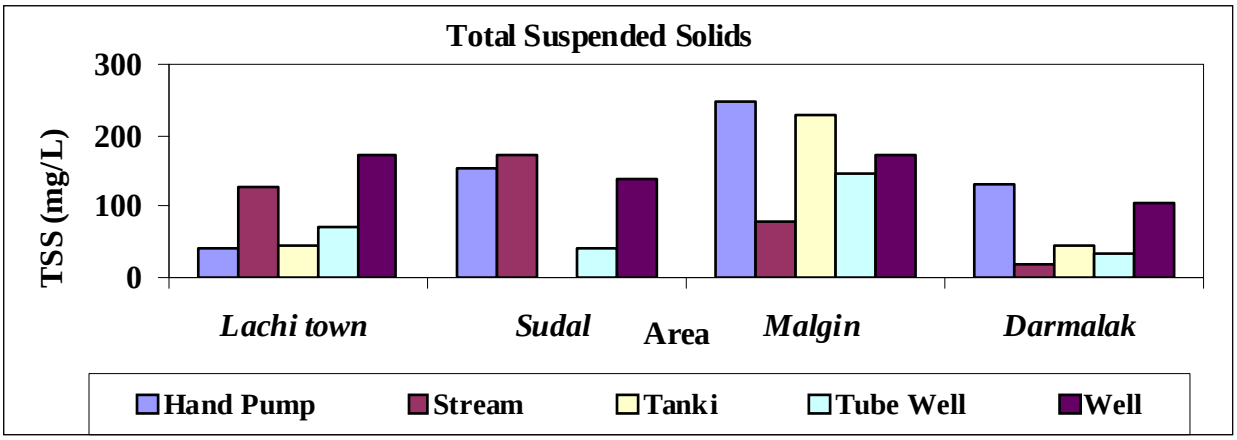

Figure 5. Total suspended solids of water samples

Chemical parameters

Total alkalinity values of the studied drinking water samples ranged between 99 to 259 mg/L. The lowest was observed in the Malgin stream while the highest was found in Lachi town hand pump. Among the bottled water total alkalinity values varied from 16 to 48 mg/L (Table 3, Figure 6). On comparison of the results, it was found that all the drinking water samples were

having total alkalinity values within the WHO/Pakistan standard value for total alkalinity in drinking water (500 mg/L) (Table 1) (25-29). These results are supported by Khan et al (2012b) (21). Thus on the basis of total alkalinity, water sources are safe and can be used for drinking and other usual domestic purposes.

Table 3. Chemical parameters (mg/L)

Area	Source	Total Alkalinity	Hardness as $CaCO_3$			Chloride (Cl^-)	Sodium (Na)	Potassium (K)
			Total hardness	Ca hardness	Mg hardness			
Darmalak	Hand pump	237	1132	827	305	783	950	14.0
	Stream	209	619	329	290	172	124	5.0
	Tank	216	528	389	139	187	56	7.0
	Tube well	207	451	285	166	165	94	5.0
	Well	211	558	332	220	773	504	5.5
Lachi town	Hand pump	259	168	139	29	203	96	5.2
	Stream	188	2593	1366	1227	1640	360	8.0
	Tank	187	456	362	94	192	60	4.5
	Tube well	124	976	729	247	697	102	2.0
	Well	149	2388	1722	666	1987	190	8.2
Malgin	Hand pump	208	1241	673	568	343	264	4.5
	Stream	99	544	280	260	88	54	14.0
	Tank	163	709	392	317	692	204	3.0
	Tube well	163	1275	824	451	407	108	4.5
	Well	163	623	501	122	403	222	3.5
Sudal	Hand pump	176	586	427	159	590	525	6.5
	Stream	312	623	276	347	402	392	5.5
	Tube well	181	683	503	180	323	110	2.5
	Well	157	815	474	341	283	80	7.0
Bottle Water	Aquafina	16	168	125	43	79	17	2.0
	Kinley	27	248	199	49	140	14	2.0
	Nestle	48	270	206	64	139	24	3.5

Total hardness ranged from 168 (Lachi town hand pump) to 2593 mg/L (Lachi town stream). Total hardness values of the bottled water were in the range from 168 to 270 mg/L. WHO and Pakistan standard value for total hardness in drinking water is 500 mg/L (Table 1).Thus from the results (Table 3, figure 7) it was clear that 16 (72.73%) out of total 22 samples, have total hardness value higher than the prescribed limits of WHO/Pakistan (Table 1). By keeping in view the interaction of hardness with other factors, such as pH and alkalinity, it has been determined that high water hardness cause scale deposition in pipes of the distribution systems and also the increased soap consumption (12).

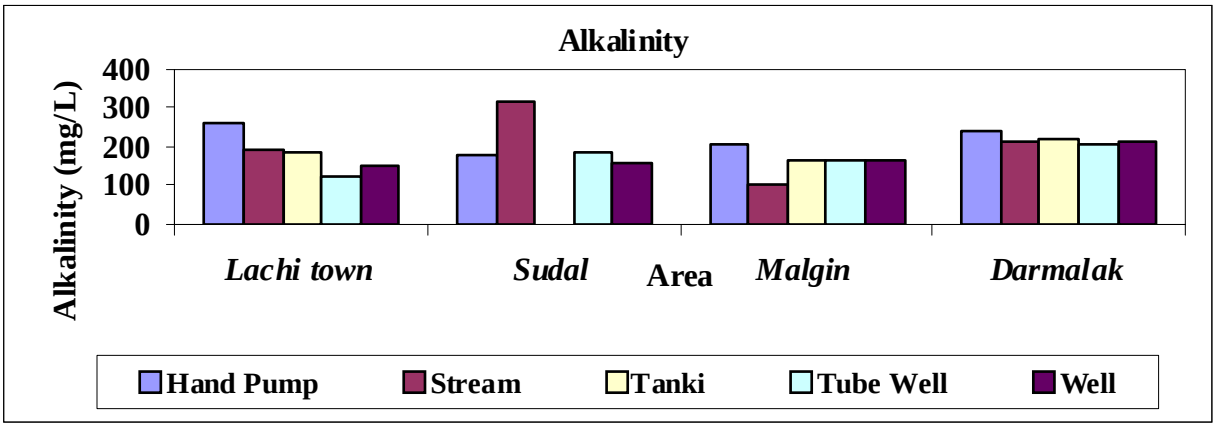

Figure 6. Total Alkalinity of water samples

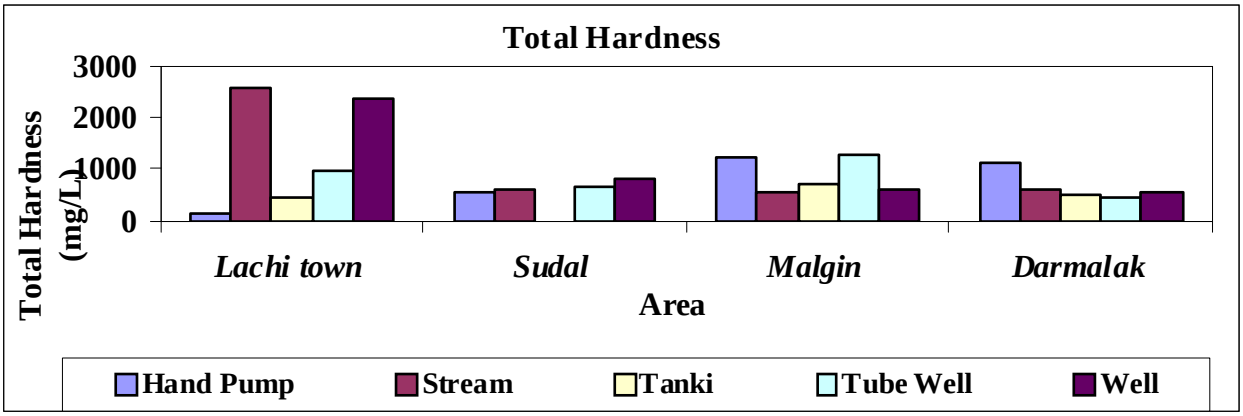

Figure 7. Total hardness of water samples

Calcium hardness was found high than the standard (75 to 200 mg/L), in all sources of all the areas except bottled water. The highly polluted samples, with calcium hardness higher than 500 mg/L, were Lachi stream, well and tube well, Malgin steam, hand pump and tube well and Darmalak hand pump (Table 3, Figure 8). The WHO guideline for magnesium in drinking water is 150 mg/L and Pakistan standard is in the range from 80 to 150 mg/L (Table 1) (26-30). Only 7 (31.82 %), out of total 22 samples were with magnesium concentrations within the recommended values (Table 3, Figure 9). Inadequate intake of Ca and Mg causes osteoporosis, nephrolithiasis, colorectal cancer, hypertension, endothelial dysfunction, coronary heart disease, diabetes mellitus and metabolic syndrome (32).

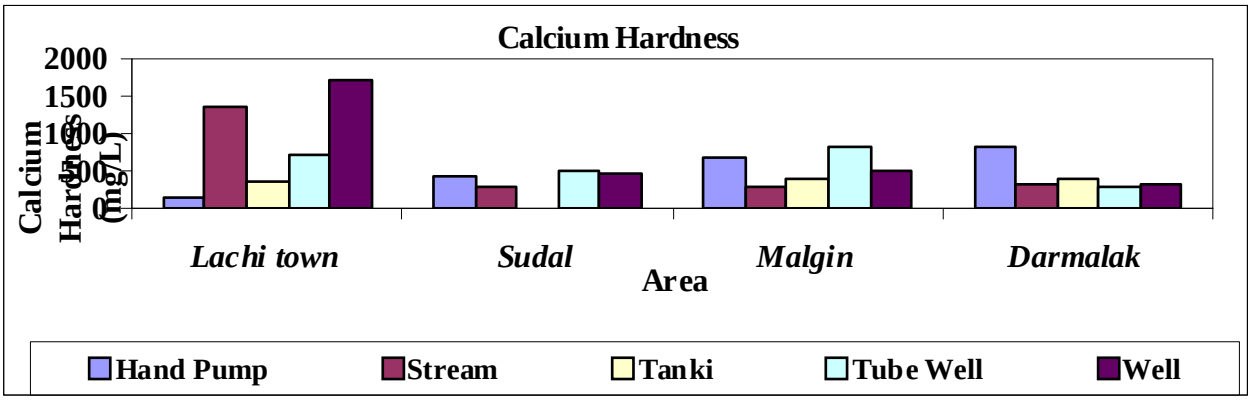

Figure 8. Calcium hardness of water samples

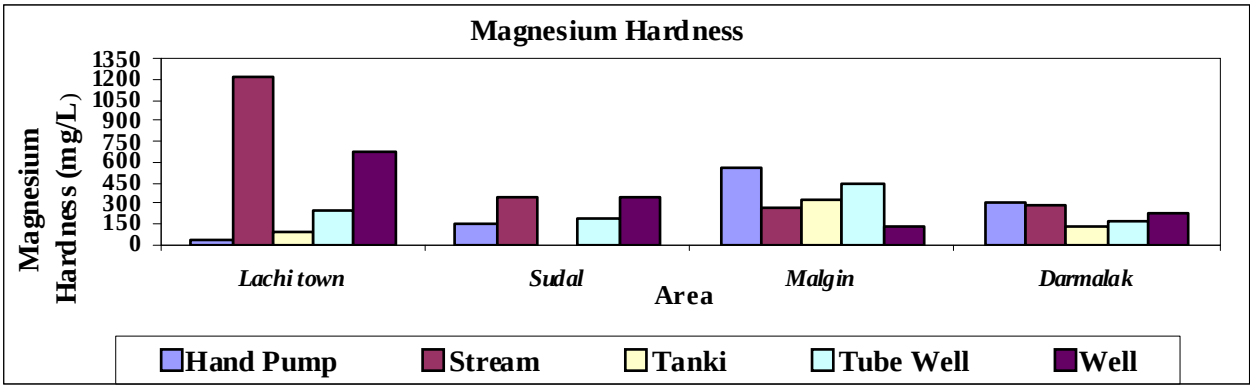

Figure 9. Magnesium hardness of water

Chloride is a commonly present in all types of rocks in many forms but its affinity towards sodium is high due to which it is present in excess in ground waters. Chlorides concentration also depends on the soil porosity and permeability (33).

WHO and Pakistan guideline value for chlorides in drinking water is 250 mg/L (Table 1). This study showed that 9 out of 22 (40.91%) water samples have chloride concentrations in the permissible limits. The most polluted sources with chloride values above 500 mg/L were Lachi town, well (1987 mg/L) and stream (1640 mg/L), Darmalak, hand pump (783 mg/L) and well (773 mg/L), Lachi town tube well (697 mg/L), Malgin tank (692 mg/L) and Sudal hand pump

(590 mg/L) (Table 3, Figure 10). High chloride concentration results in the high conductivity which is considered to be a risk for human health and may cause unpleasant taste (34).

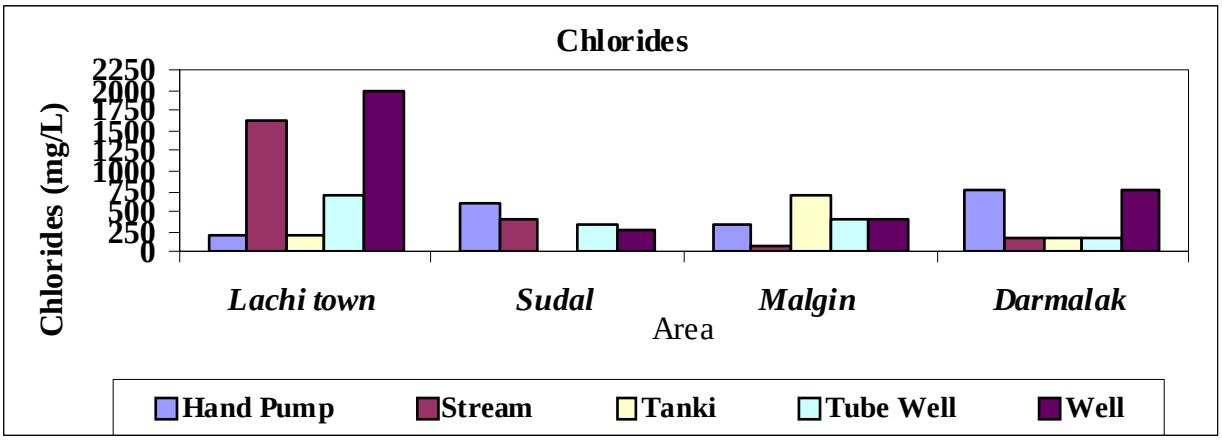

Figure 10. Chloride values of water samples

The value of sodium in the drinking water samples was found in the range from 54 to 950 mg/L. The lowest was found in the Malgin stream and the highest in Darmalak hand pump. Sodium concentration in bottled water ranged from 17 to 24 mg/L (Table 3, Figure 11). Total 14 samples out of 22 (63.64 %) were containing sodium concentration in the WHO/Pakistan permissible limit (200 mg/L) (Table 1). The most polluted samples were Sudal hand pump (525 mg/L), Darmalak hand pump (950 mg/L) and well (504 mg/L). High level of sodium in water is associated with disorders in heart, kidneys and complications in pregnancy. Also elevated levels of sodium in water damage domestic plumbing systems, water heaters and municipal water work equipments. So the water containing high concentration of sodium is not safe for drinking and other domestic use (35).

Potassium values ranged between 2 to 14 mg/L. Among the bottled water it varied from 2.0 to 3.5 mg/L (Table 3, Figure 12). All water samples contained potassium in the acceptable limit according to Pakistan standards (30 mg/L). However Malgin stream and Darmalak hand pump contained 14 mg/L, which were high than the WHO limit (12 mg/L) (Table 1), (26-30). These results are in accordance to our previous study (22). In healthy individuals, high levels of potassium (up to 3700 mg/day) possess no harmful effects because potassium is rapidly excreted. A very high dose of potassium results in chest tightness, nausea, vomiting, diarrhea, hyperkalaemia, shortness of breath and heart failure (36).

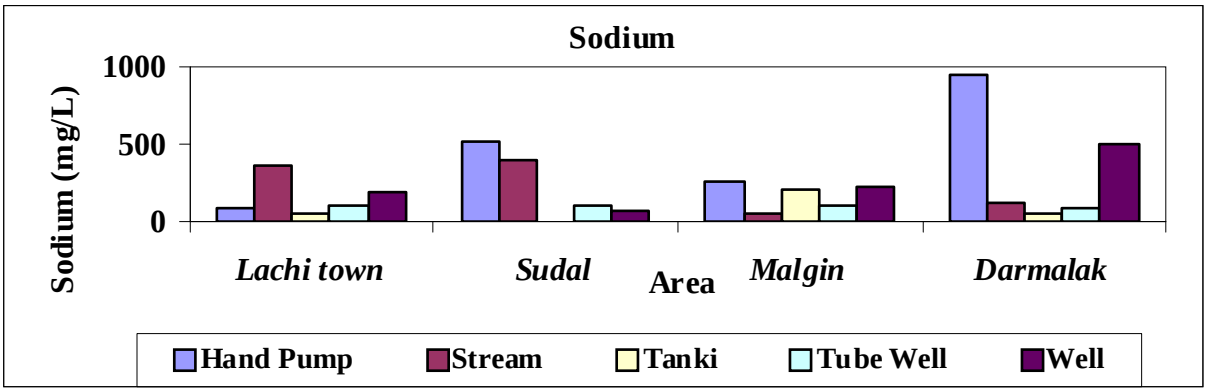

Figure 11. Sodium values of water samples

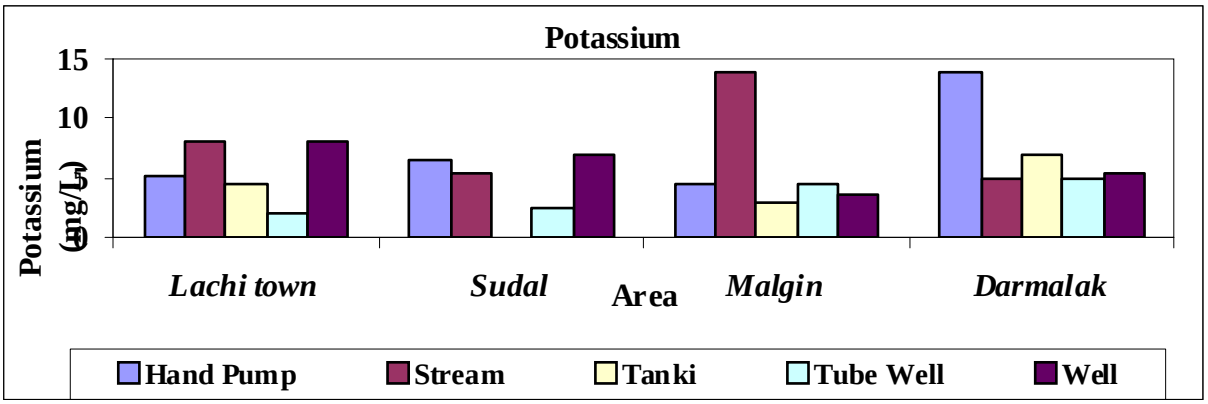

Figure 12. Potassium values of water samples

Heavy Metals

The values of arsenic varied between 1.627 to 3.115 mg/L, the lowest was found in Lachi town stream and highest was in Lachi tube well. Among the bottled water, it ranged from 1.602 to 2.857 mg/L (Table 4, Figure 13). WHO and Pakistan Standard for arsenic in drinking water is 0.01-0.05 mg/L (25-29). The values of arsenic in all the samples was high than the WHO and Pakistan Standards (Table 1). Arsenic is a carcinogen element and drinking contaminated water results in harmful effects on the digestive tract, heart, vascular system and central nervous system and even causes death up to 60 mg/L in drinking water (37).

Table 4. Heavy metals (mg/L)

Area	Source	Arsenic (As)	Selenium (Se)	Lead (Pb)
Darmalak	Hand pump	3.053	1.416	0.455
	Stream	1.916	1.628	0.455
	Tank	2.670	1.895	0.461
	Tube well	2.630	1.734	0.446
	Well	2.301	1.314	0.454
Lachi town	Hand pump	2.537	1.715	0.497
	Stream	1.627	1.493	0.506
	Tank	2.599	1.321	0.488
	Tube well	3.115	1.586	0.491
	Well	3.034	1.555	0.509
Malgin	Hand pump	1.885	1.465	0.394
	Stream	1.859	1.551	0.433
	Tank	2.339	1.711	0.446
	Tube well	1.700	2.192	0.418
	Well	2.240	1.560	0.412
Sudal	Hand pump	2.782	0.877	0.388
	Stream	1.921	1.182	0.372
	Tube well	2.275	1.646	0.391
	Well	2.076	1.186	0.385
Bottle Water	Aquafina	2.857	1.238	0.534
	Kinley	1.602	1.431	0.524
	Nestle	2.350	1.900	0.509

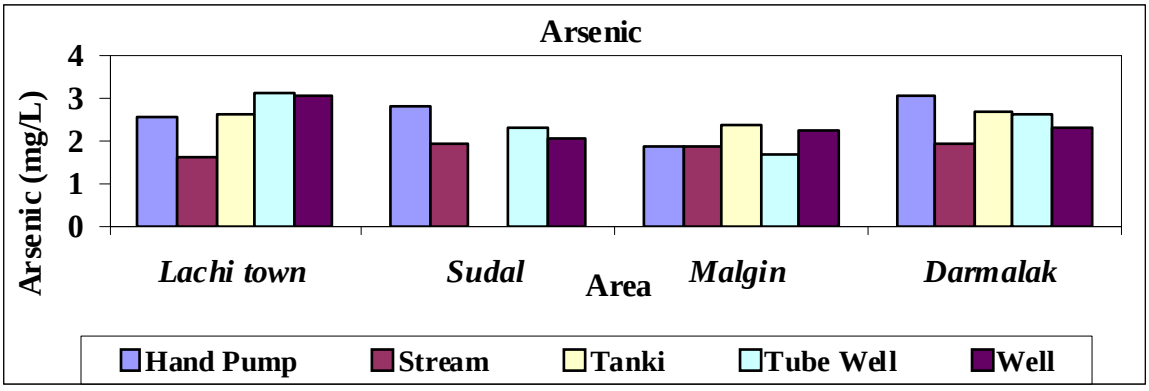

Figure 13. Arsenic values of water samples

Lead concentration ranged between 0.385 – 0.534 mg/L. The lower value of lead was obtained in the Sudal well and higher value was observed in the Aquafina bottled water. The concentration

of lead among the bottled water varied in the range from 0.509 to 0.534 mg/L (Table 4, Figure 14). The value of lead specified by the WHO and Pakistan Standards water is 0.01 mg/L (25-29). Thus all the sources were found contaminated with lead. These results are supported by Farid et al (2012) (19). Harmful health effects of high lead concentrations in drinking water include various types of cancers, cardiovascular and neurological diseases, problems in the synthesis of haemoglobin, effects on the kidneys, gastrointestinal tract, joints and reproductive system (38).

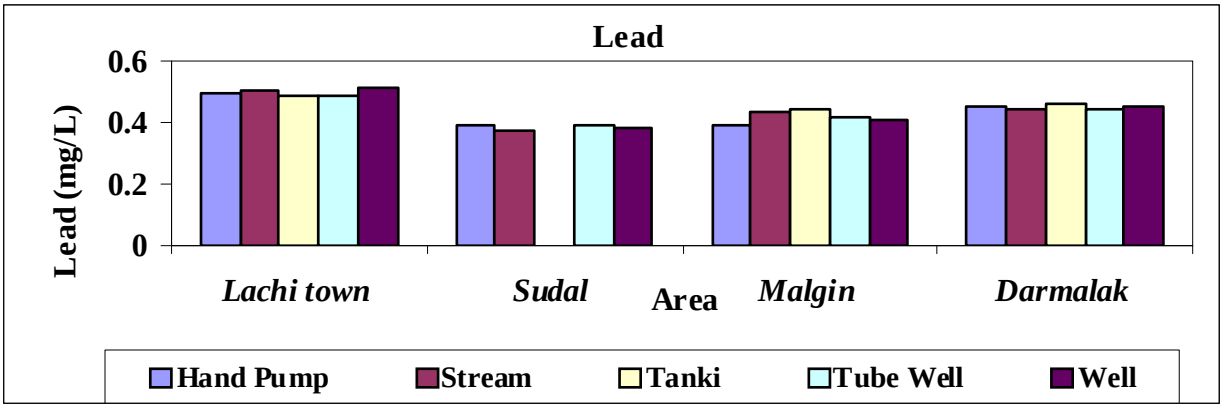

Figure 14. Lead values of water samples.

The value of selenium in drinking water specified by the WHO/Pakistan Standards is 0.01 mg/L, and the values of selenium in the drinking water samples studied varied in the range from 0.877 to 2.192 mg/L, being lowest in the Sudal hand pump while highest was in Malgin tube well. Selenium concentration among the bottled water was found in the range from 1.238 to 1.900 mg/L (Table 4, Figure 15). So selenium concentration in all the samples was higher than the WHO/Pakistan Standards. Selenium recommended daily intake for human is 1µg/kg of body weight. Selenium compounds are often genotoxic in vitro systems. In humans, long-term selenium exposure causes disorders in nails, hair and liver (39).

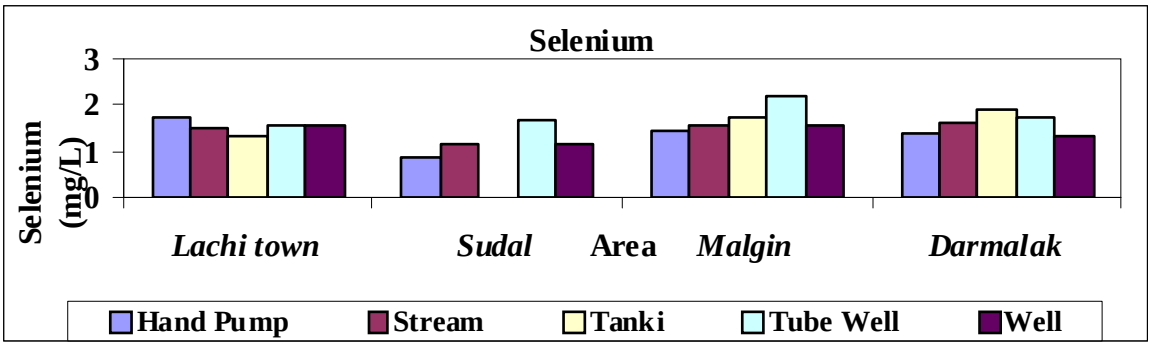

Figure 15. Selenium values of water samples.

Conclusions

Most of the samples analyzed were found contaminated either due to one or more parameters. Only pH, alkalinity and potassium values of all the samples were in the permissible range. Heavy metals in all samples crossed the WHO and Pakistan Standards. Arsenic is carcinogenic and therefore its presence is a serious threat. In nutshell from the results, it is concluded that the quality of drinking water Lachi area is worse and it is suggested that drinking water must be treated before supply.

Acknowledgments

The authors thank Prof. Abdul Naeem Khan, National Centre of Excellence in Physical Chemistry, University of Peshawar, Pakistan, for providing laboratory facilities.

References

1. Nevondo VS, Cloete ST. Reclamation of ponds, lakes, and steams with fish toxicant. a review of food and agriculture organization of the United Nations, FAO. Fish Tech Pap; **1991**. 100: 57-61.

2. Dara SS. A textbook of Environmental chemistry and pollution control, New Delhi, **1997**. Chand Publishing Company, India.

3. Ahmad R. Studies on the chemistry control of some selected drinking and industrial waters Pakistan. J Sci Ind Res; **2005.** 48(3): 174-179.

4. Joyce TM, Meguigan KG, Elmore-Meegan M, Conroy RM. Inactivation of Fecal Bacteria in Drinking Water by solar heating. J Appl Environ Microbiol; **1996.** 62: 399-402

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

6. Leoni EGD, Legnani PP, Sacchetti R, Spampi S, Zanetti F. Legionella. Waterline Colonization: Detection of Legionella species in Domestic, Hotel and Hospital Hot Water System. J Appl Microbiol; **2005.** 98(2): 373-379.

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

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

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

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

11. Aydin A. The microbiological and physico-chemical quality of ground water in west Thrace, Turkey. Polish J of Environ. Stud; **2007.** 16(3): 377-383.

12. Gupta DP, Sunita, Saharan JP. Physiochemical analysis of ground water of selected area of Kaithal city, Haryana, India. Researcher; **2009.** 1(2): 1-5.

13. Gyamfi ET, Ackah M, Anim AK, Hanson JK, Kpattah L, Brown SE, Kyereme ES. Chemical analysis of potable water samples from selected suburbs of Accra, Ghana. Proceedings of the International Academy of Ecology and Environmental Sciences. **2012**. 2(2):118-127.

14. Tahir MA, Chandio BA, Abdullah M, Rashid A. Drinking water quality monitoring in the rural areas of Rawalpindi. In proceedings of the national workshop on quality of drinking water. Islamabad, Pakistan Council of Research in Water Resources. **1998.** 35-39.

15. Chilton PJ, Jamieson D, Abid MS, Milne CJ, Ince ME, Aziz JA. Pakistan water quality mapping and management project. scoping study. Draft final report. **2001**. Water engineering and development centre, Loughborough University & London School of Hygiene & Tropical Medicine, WELL Task 568. Loughborough, UK.

16. Rahman AU. Ground water as Source of contamination for water supply in rapidly growing mega cities of Asia: Case of Karachi, Pakistan. Water Sci Technol; **1996**. 34(7-8): 285-292.

17. Malana MA, Khosa MA. Ground water pollution with special focus on arsenic, Dera Ghazi Khan. Pakistan. J of Saudi Chem Soc; **2011** 15: 39–47.

18. Baig SA, Xinhua XU, Nadeedullah, Muhammad N, Khan ZU, Nawab B, Mahmood Q, Khan R, Pakistan's drinking water and environmental sanitation status in post 2010 flood scenario: humanitarian response and community needs. J Appl Sci Environ Sanit; **2012.** 7(1): 49-54.

19. Farid S, Baloch MK, Ahmad SA. Water pollution: Major issue in urban areas Int J Water Res Environ. Engg; **2012**. 4(3): 55-65.

20. Naeem K, Tasleem SH, Saboor A, Nargis J, Ahmed S, Ullah R, Ullah Z, Ali S, Lee SI, Kim KS. Bacteriological investigation of ground water sources in selected urban areas of district Mardan, Khyber Pakhtunkhwa, Pakistan. Afr J Biotechnol; **2012**. 11(51): 11236-11241.

21. Naeem K, Tasleem SH, Javid H, Nargis J, Ahmed S, Ullah R, Ullah Z. Physiochemical evaluation of the drinking water sources from district Kohat, Khyber Pakhtunkhwa, Pakistan. Int J Water Res Environ. Engg; **2012b.** 4(10), pp. 302-313.

22. Naeem K, Tasleem SH, Javid H, Nargis J, Shabir A, Riaz U, Zain U, Samina A, Saboor A, Chemical and microbial investigation of drinking water sources from Kohat, Pakistan Int. J Phy Sci; **2012c**. 7(26), 4093-5002.

23. Memon M, Soomro MS, Akhtar MS, Memon KS. Drinking water quality assessment in southern Sindh (Pakistan). Environ Monit Assess; **2011.** 177:39–50.

24. APHA. American public health association, standard methods for the examination of water and waste water. **1998.** 20th edn. USA.

25. WHO. World Health Organization. Guidelines for drinking water quality, health criteria and other supporting information, Geneva, **1996**. 2nd edn. 2.

26. 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, **1998**. 20th Edition, Washington, DC. USA.

27. PCRWR. 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,. Available online at; http://www.pcrwr.gov.pk/wq_phase2_report/chapter_no3.pdf

28. WHO. World Health Organization. **2006**. Guidelines for drinking-water quality, first addendum to 2nd edn, Recommendations, 1.

29. NSDWQ. National standards for drinking water quality, Pakistan environmental protection agency, ministry of environment, government of Pakistan, **2008**. pp 4-7. Available online at: http://www.freshwateraction.net/sites/freshwateraction.net/files /Drinking %20 water%20in%20Pakistan.pdf

30. Bajracharya AM, Yami KD, Prasai T, Basnyat SR Lekhak B. Assessment of drinking water quality of Kathmandu metropolitan areas. Nep J Sci Technol; **2007**. 8, 113-118, 2007.

31. Anonymous Ground water quality, Ohio department of natural resources, division of water, fact sheet, **1997.** Available at: http://www.dms.stateoh.us/water/pubs/pdfs/fctsht42.pdf

32. Altman D, Carroli G, Duley L, Farrell B, Moodley J, Neilson J, Smith D. Do women with pre-eclampsia, and their babies, benefit from magnesium sulphate? the Magpie trial: a randomised placebocontrolled trial. Lancet; **2002.** 359(9321): 1877-1890.

33. Ramakrishnaiah CR, Sadashivaiah C, Ranganna AG. Assessment of water quality index for the groundwater in Tumkur Taluk, Karnataka State, India. E J Chem; **2009**. 6 (2), 523-530.

34. Versari A, Parpinello GP, Galassi S. Chemometric survey of Italian bottled mineral waters by means of their labelled physico-chemical and Chemical Composition. J Food Compos Anal; **2002**. 15: 251–264.

35. Obi CN, Okocha CO. Microbiological and physicochemical analysis of selected bore-hole waters in the World Bank Housing Estate, Umuahia, Abia State, Nigeria. J Eng Appl Sci; **2007**. 2 (5): 920-929.

36. Restuccio A Fatal hyperkalaemia from a salt substitute. Am J Emerg Med; **1992.** 10: 171–173.

37. Javadi A, Khatibi SA, Khakpour M, Ganjali M, Ghorbanpour H. Evaluation of arsenic, magnesium and calcium in the drinking water at Ghouri-Goul region in Tarbiz. Res J Appl Sci; **2009**. 4 (5): 185–188.

38. Nnanna OJ, Nathaniel DC, Chinedu AN, Ekwutosi OT. Physicochemical quality of municipal borehole water in Imo State, Nigeria. Pak J Med Res ; **2009**. 48(1):8-11.

39. WHO. World Health Organization. Selenium in drinking-water: **2003.** background document for preparation of WHO guidelines for drinking-water quality.