Asian Journal of Chemistry; Vol. 27, No. 5 (2015), 1658-1662

ASIAN JOURNAL OF CHEMISTRY

http://dx.doi.org/10.14233/ajchem.2015.17443

Post-Earthquake Impact on Quality of Spring Water in Northern Pakistan

M. ASLAM MIRZA[1,*], M.Y. KHUHAWAR[2], R. ARAIN[2], M. AZIZ CHOUDHARY[1] and KHALIDA PARVEEN MAHAR[3]

[1]Mirpur University of Science and Technology, Mirpur, Pakistan
[2]Institute of Advanced Research Studies in Chemical Sciences, University of Sindh, Jamshoro, Pakistan
[3]Department of Chemistry, Shah Abdul Latif University, Khairpur, Sindh, Pakistan

*Corresponding author: Tel: +92 5827 961100; E-mail: ma_mirza64@yahoo.com

Received: 22 February 2014; *Accepted*: 17 May 2014; *Published online*: 20 February 2015; AJC-16863

This study was in progress before earth quake of October 8, 2005 and was extended to assay the post-earthquake impact on the spring water quality in highly devastated areas near the epicenter. The distressed area is situated at the foothills of Himalayas forming primarily the catchments area of Indus river. Thirteen springs were re-sampled 1 month after the earth quake in 2005. The preliminary results indicate TDS for half of the water samples within 115-499 mg/L, for the remaining half it exceeds 500 mg/L. Inter sample, seasonal and hydrological cycle variance indicate no significant change in elemental composition but those contaminated with sewage of deforested locations show substantial variation in elemental content. Low rainfall also deters the dilution of pollutants occurring both naturally and through human activity. This study provides the database of the quality of water of springs in the targeted area.

Keywords: Spring water quality, Earth-quake impact, Physico-chemical assay.

INTRODUCTION

Northern region of Himalayan series of mountains was struck by earthquake (a magnitude M_w = 7.6) on October 8, 2005. The epicenter of earthquake was located approximately 9 km northeast of Muzaffarabad city. Lifelines were adversely affected, especially the numerous vital roads and highways that were closed by landslides and bridge failures. Massive land sliding was a particular feature of this event. A very dense, high-frequency band of landslides was triggered along the fault rupture trace in the midslope areas. However, it quickly dissipated with distance away from the fault rupture zone. Almost all landslides were shallow, disaggregated slides, with two of them larger than 0.1 km[1-3]. Ubiquitous shallow landslides and rock falls on steep natural slopes and in steep road cuts were initiated during the earthquake. They posed the largest threat to mountain roads and structures at slope bases. Deep-seated landslides were far less numerous than shallow slides. Rock falls involving large rocks or boulders were common and resulted in considerable damage and disruption to roadways, structures and communities. Many such slides, triggered by frequent after shocks, resulted in significant fatalities. Major damage concentrations in Muzaffarabad were in areas of deeper alluvial deposits along the Neelum and Jhelum rivers[4,5].

Water supply system: Private water storage in the form of roof-mounted storage tanks is prevalent in the area. In the earthquake zones, many overhead water tanks shifted or collapsed. Municipal water supply to Muzaffarabad comes from the river Neelum. River water is lifted from six intake lines and treated in a series of rapid sand filters and clarifiers. Damage to this water system ranged from damage to clarifier baffles, motor control units and distribution piping in some areas. With help from UNICEF, the system was repaired fairly quickly-untreated water was returned within five days and treated water was available ten days following the earthquake. In smaller villages and hamlets, water comes from private ground water wells or natural streams. In one case, a hamlet located between Mansehra and Ghari Habibullah experienced a significant drop in water elevation in its wells two weeks after the earthquake and the locals reported high turbidity[5].

The present work covers a representative study of the catchments area of the Indus river at the foot hills of Himalayas with a population of more than 3.2 million (population density: 330 persons/km^2)[6]. The results of this preliminary study provide a credible guideline and a data base on spring water and variation in its quality. Three tributaries Neelum, Jhelum and Poonch rivers across the studied area of more than 13000 Km^2 with their stock of spring water, snow melt and surface run-off from the mother stream of Indus river. Concurrently, human activities in the recharge area also bring about significant changes in spring water, affecting human health[1]. In urban areas like Muzaffarabad, Bagh, Bhimber, Mirpur and

Kotli, the main sources of spring water contamination are leaking sewage systems, gasoline stations, septic tanks, domestic and industrial effluents and leachate from waste disposal sites[7-10]. Rapid urbanization, level of industrial activity and population growth in the area has increased significantly the elemental composition of drinking and irrigation water because of the effluents from post redox industrial processes[9,10]. Saddle-shaped ridges where most of the towns have been developed also happen to be the recharge area of these springs[11,12]. The domestic sewage of the towns is disposed of untreated through landfills and unlined open drains. In haphazardly growing towns of Authmuqam, Palandri, Trarkhal, Fatehpur, Rawalakot, Abaspur, Dhirkot, Charhoi, Hattian and Haveli, the pollution of surface water is obvious and is due to shallow soil column in the town areas for reverse osmosis of polluted surface water and the removal of its contaminants before being added as recharge to the subsoil water stock. The polluted subsoil water thus re-emanates with spring discharge[13-15].

Sampling: Before sampling, a thorough survey of the area was undertaken. Spring location and *in situ* testing of physico-chemical parameters was carried out in order to plan proper sampling strategy. The purpose of the field survey was to trace and select the springs from the most devastated areas for the study. Since springs represent underground water[16], thirteen perennial springs having ample discharge all the way through the year were selected for this study.

Many springs are present as cave type depressions within the mountains while others in simulated well type depressions. Most of the water used from the springs is rejuvenated during the night. Some of the springs also indicate continuous flow of water, which is either stored in artificial basin or is reabsorbed in the bed[17-19].

Mode: The sampling mode was simple grab method. At predetermined depths pre-washed high density polythene bottles were suspended from the surface through a Secchi disc and the stopper was removed by a sharp jerk through an attached line. Each spring was sampled at the extremes laterally, in the middle and vertically at varying depths at these points of the stream. Sub-samples thus taken were soon after integrated into a composite sample. Field measurements included conductivity, pH and temperature of the stream and air. For elemental analysis each sample was acidified to pH < 2; for organic matter, fixed with $HgCl_2$. Separate samples were taken for precise analysis.

EXPERIMENTAL

Chlorides, hardness and bicarbonates were estimated by titration with silver nitrate, standard EDTA and hydrochloric acid, respectively. The pH was noted with Orion 420 A pH meter. Conductivity, total dissolved solids (TDS) and salinity were recorded with Orion 115 conductivity meter[16]. Hitachi 220 spectrophotometer was used for the determination of Sulphate by turbidimetery as $BaSO_4$. The metal ions Ca, Mg, Na, K, Pb, Fe, Zn, Cu, Cd, Ni and Co were determined with Varian Spectr AA-20 atomic absorption spectrometer. The analysis was performed in triplicate with delay and integration time 3 second each. Major metals (Na, K, Ca and Mg) were determined after appropriate dilution. Sample (300 mL) containing nitric acid (1 mL) was heated quietly at about 90 ºC and was concentrated to about 10 mL. The solution was transferred to volumetric flask and final volume adjusted to 15 mL[16,17]. The solution was analyzed for the contents of Cu, Zn, Fe, Pb, Ni, Cd and Co by air acetylene flame atomic absorption spectrometer.

RESULTS AND DISCUSSION

Springs: For post-quake study, 13 springs were selected from medium to high devastation areas to assess the impact of 2005 Pakistan Earthquake on the quality of water in the study area. The physicochemical parameters selected for the comparison were pH, electrical conductivity, total dissolved solids, salinity, total hardness, bicarbonates, chlorides, sulphates, K, Na, Mg, Ca, Fe, Cu, Pb, Cd, Ni, Zn and Co. Pre-quake study was spread over in three seasons of a hydrological cycle and final results were averaged and taken as bench marks for comparison with post-quake trends of water quality.

EC, TDS, pH, salinity, total hardness, bicarbonates, chlorides and sulphates: EC, TDS, pH and salinity indicated almost the same trends in pre and post-quake environment, likewise variation in total hardness, bicarbonates, chlorides and sulphates also remained insignificant in the selected springs S_1 to S_{13} (Tables 1, 2) (Figs. 1, 2).

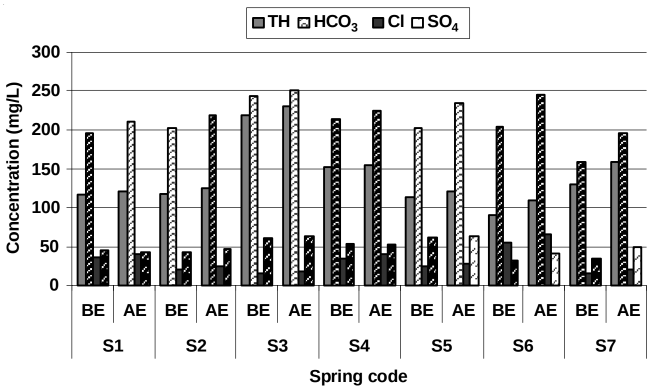

Fig. 1. Distribution of total hardness, bicarbonate, chloride and sulphate in the water of springs before and after earthquake

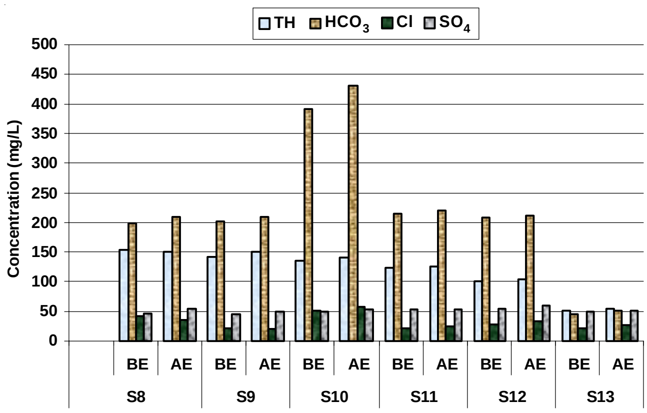

Fig. 2. Distribution of total hardness, bicarbonate, chloride and sulphate in the water of springs before and after earthquake

Major metal contents (Na, K, Ca and Mg): Major metal contents (Na, K, Ca and Mg) were reanalyzed after 2 months of 2005 Pakistan earthquake and their values investigated were within the range: Na 9.3-142.2, K 0.019-11.15, Ca 22.68-164.5 and Mg 13.52-39.2 mg/L while the values estimated for the

TABLE-1
PHYSICOCHEMICAL DATA DEPICTING THE IMPACT OF EARTHQUAKE ON THE QUALITY OF SPRINGS WATER

Parameters	S_1		S_2		S_3		S_4		S_5		S_6		S_7	
	BE	AE	BE	AE	BE	AE	BE	AE	BE	AE	BE	AE	BE	AE
pH	6.65	6.39	6.8	6.98	7.12	7.22	6.3	6.21	7.12	7.03	7.12	7.11	7.2	7.14
EC	701	704	738	747	846	851	815	825	521	530	460	494	502	546
TDS	449	451	472	478	541	544	522	529	333	339	294	316	321	319
Sal.	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.2	0.2	0.3	0.3
TH	116	120	119	125	187	230	149	155	114	120	91	110	130	160
HCO_3	195	210	203	220	213	250	205	225	202	235	204	245	160	195
Cl	35.8	38.6	20.9	24.8	15.3	17.7	34.5	39.0	24.0	28.0	55.1	65.3	15.2	21.3
SO_4	45.2	43.6	43.0	46.6	59.4	63.8	53.2	51.7	61.0	64.1	31.2	40.5	33.5	48.9
Na	10.2	9.3	35.0	31.4	133	142	20.4	18.2	21.0	29.1	37.1	48.2	16.2	19.3
K	7.21	5.06	12.0	10.1	12.2	10.2	7.9	9.0	1.1	2.22	8.2	11.2	3.4	6.36
Ca	110.5	116.3	75.0	81.4	23.8	22.7	91.3	97.8	120	164.5	39.0	44.0	89.0	104
Mg	21.3	24.1	32.0	34.9	19.3	22.3	34.5	36.8	12.0	18.8	18.0	22.4	11.3	15.8
Fe	0.03	0.031	0.04	0.036	0.007	0.008	0.01	0.007	0.02	0.056	0.03	0.063	0.01	0.02
Cu	0.004	0.005	0.001	0.002	0.003	0.004	0.007	0.008	0.001	0.006	0.001	0.003	0.001	0.003
Pb	0.041	0.042	0.02	0.030	0.03	0.031	0.031	0.033	0.002	0.009	0.004	0.008	0.009	0.022
Cd	0.009	0.001	0.001	0.001	0.001	0.001	0.0	0.0	0.001	0.004	0.001	0.003	0.008	0.001
Ni	0.026	0.028	0.002	0.026	0.03	0.022	0.02	0.023	0.003	0.022	0.01	0.020	0.011	0.017
Zn	0.017	0.020	0.007	0.009	0.012	0.013	0.001	0.003	0.001	0.004	0.004	0.006	0.001	0.003
Co	0.021	0.022	0.019	0.020	0.038	0.043	BDL	0.018	BDL	BDL	BDL	BDL	0.009	0.02

Selected springs: S_1: Jandichountra Spring-Bhimber S_2: Spring near boys' degree college Pallandi Disrict Sudhnoti S_3: Housing Scheme spring Rawalakot District Poonch S_4: Parat spring District Poonch S_5: Main supply Bagh spring near lari adda District Bagh S_6: Hari Ghail spring District Bagh S_7: Dheer Kot Jamia Masjid spring District Bagh; BE: Before earthquake; AE: After earthquake

TABLE-2
PHYSICOCHEMICAL DATA DEPICTING THE IMPACT OF EARTHQUAKE ON THE QUALITY OF SPRINGS WATER

Parameters		S_8		S_9		S_{10}		S_{11}		S_{12}		S_{13}	
	Units	BE	AE	BE	AE	BE	AE	BE	AE	BE	AE	BE	AE
pH	-	7.03	7.01	6.89	6.61	6.87	6.97	6.69	6.73	7.3	7.01	7.65	7.68
EC	µS/cm	517	522	735	731	1085	1098	831	839	820	827	268	275
TDS	mg/L	331	334	470	468	694	703	532	537	525	529	171.5	176
Sal.	mg/L	0.2	0.2	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.4	0.1	0.1
TH	mg/L	155	150	142	150	136	140	123	125	99.8	105	52	55
HCO_3	mg/L	197	210	201	210	390	430	215	220	208	212	45	51
Cl	mg/L	41.0	35.45	23	21.27	52.0	56.72	22.9	24.82	29.2	31.91	22.0	26
SO_4	mg/L	48.0	55.7	46.0	50.0	49.0	52.7	54.2	52.7	56.0	59.0	49.0	52.3
Na	mg/L	14.0	18.0	27.0	29.24	82.0	80.0	30.2	32.9	139.8	142.2	18.0	19.4
K	mg/L	0.014	0.019	6.2	7.92	8.9	10.9	10.2	8.92	6.7	7.80	6.1	7.42
Ca	mg/L	101	109.2	110	107.3	81.9	84.4	91.0	94.5	109	112.2	39.0	41.6
Mg	mg/L	16.2	19.7	33	36.1	36.0	38.8	36.0	39.2	29.8	31.7	10.2	13.5
Fe	mg/L	0.013	0.018	0.014	0.015	0.04	0.043	0.024	0.025	0.018	0.020	0.012	0.017
Cu	mg/L	0.001	0.003	0.006	0.005	0.005	0.006	0.008	0.009	0.002	0.003	0.003	0.004
Pb	mg/L	0.002	0.027	0.003	0.031	0.037	0.038	0.04	0.030	0.026	0.025	0.02	0.012
Cd	mg/L	BDL	BDL	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.0	0.001
Ni	mg/L	0.016	0.019	0.023	0.024	0.031	0.030	0.025	0.026	0.030	0.029	0.006	0.007
Zn	mg/L	0.005	0.008	0.014	0.016	0.015	0.016	0.018	0.019	0.023	0.022	0.006	0.005
Co	mg/L	0.02	0.023	0.021	0.022	0.022	0.023	0.021	0.022	0.024	0.022	0.018	0.20

Selected springs: S_9: Bawli Bazar Abbaspur spring District Poonch S_{10}: Domail spring Mazaffarabad S_{11}: Spring below bridge Hajeera Town District Poonch S_{12}: Kamal Nala Dheer Kot spring District Bagh S_{13}: Ziarat spring Athmaqam spring District Mazaffarabad; BE: Before earthquake; AE: After earthquake

same sampling stations before the earthquake were: Na 14-133, K 0.014-12.2, Ca 23.8-120 and Mg 10.2-36.0 mg/L. An insignificant impact of the earthquake was observed and even the springs (S_5-S_8 and S_{13}) located in highly affected areas indicated slightly higher concentrations may possibly be due to land sliding during the earthquake and heavy rains after the earthquake (Tables 1 and 2) (Figs. 3 and 4).

Minor metal ions (Fe, Cu, Pb, Cd, Ni, Zn and Co): None of the trends observed for minor metals persisted. Overall concentration of Cd, Ni and Zn slightly decreased whereas the concentration of Fe, Cu, Pb and Co marginally increased after the earthquake.

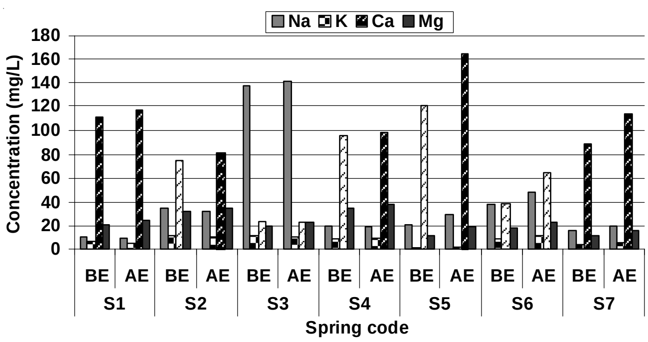

Fig. 3. Distribution of sodium, potassium, calcium and magnesium in the water of springs before and after earthquake

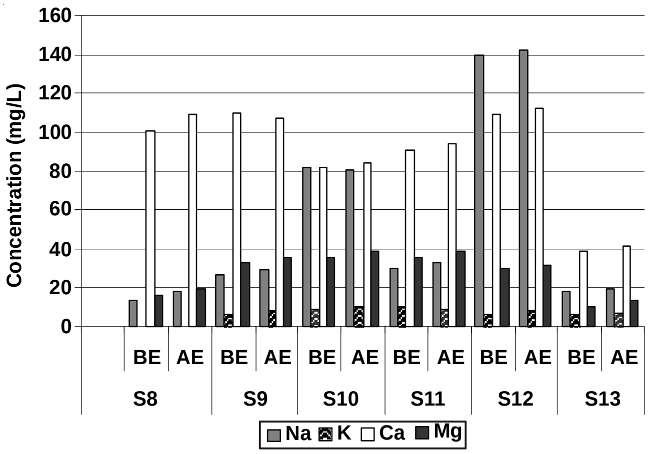

Fig. 4. Distribution of sodium, potassium, calcium and magnesium in the water of springs before and after earthquake

The concentration of Fe, Cu, Pb, Cd, Ni, Zn and Co before the quake was within the range 0.007-0.04, 0.001-0.008, 0.002-0.041, 0.0-0.009, 0.002-0.031 and 0.001-0.038 mg/L, respectively, while their concentrations after earthquake at the same sampling stations were between 0.007-0.063, 0.002-0.009, 0.008-0.042, 0.0-0.004, 0.007-0.03, 0.003-0.022 and 0.0-0.043 mg/L, respectively (Tables 1 and 2) (Figs. 5-8).

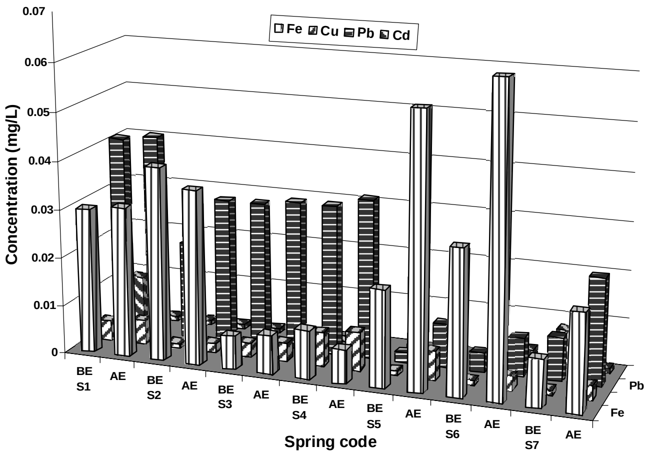

Fig. 5. Distribution of iron, copper, lead and cadmium in the water of springs before and after earthquake

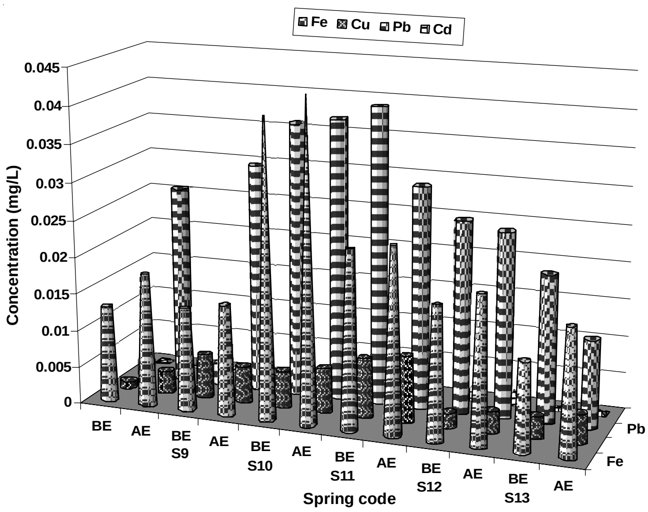

Fig. 6. Distribution of iron, copper, lead and cadmium in the water of springs before and after earthquake in 2005

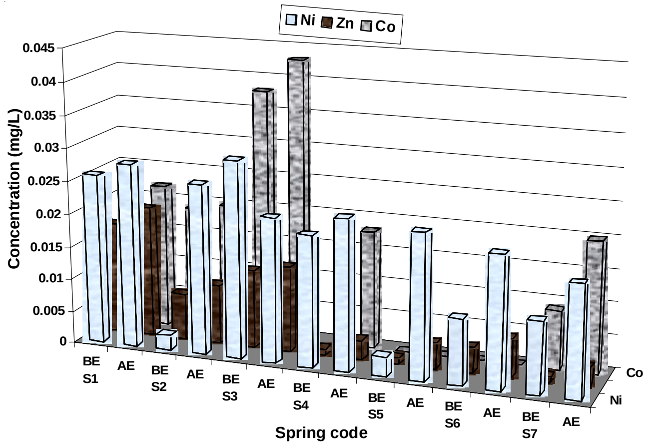

Fig. 7. Distribution of nickel, zinc and cobalt in the water of springs before and after earthquake

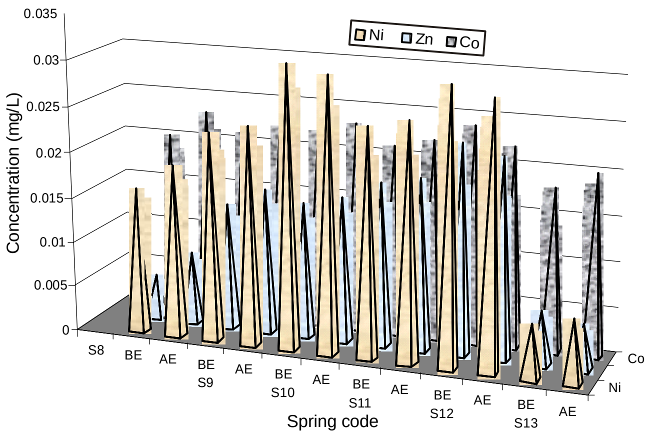

Fig. 8. Distribution of nickel, zinc and cobalt in the water of springs before and after the earthquake

Conclusions

To investigate the impact of 2005 earthquake on the surface and groundwater quality in the targeted area, 13 sampling stations (springs) were selected, re-sampled and analyzed for 19 *in situ* and lab parameters. The concluding remarks regarding this section of study are as under:

- The pH values did not indicate alteration in alkaline or acidic trends before and after the earthquake.
- An insignificant disparity in the values of the investigated parameters was observed even at the sampling stations (S_{5-8}, S_{13}) located in highly affected areas.
- In springs water no remarkable disproportion in anionic and cationic contents was observed due to earthquake.
- The springs located in the demolished city of Muzaffarabad, depicted some enhancement in the values of EC, TDS, TD and HCO_3 may possibly due to mixing of frequent avalanches during and after the earthquake.
- Overall random increasing or decreasing trends in major and heavy metal contents after the earthquake portrayed that these disproportions might be due to mingling of soil of multifarious composition brought by land sliding caused by earthquake.

REFERENCES

1. Center for the Observation and Modeling of Earthquakes and Tectonics (COMET), Locating the Kashmir Fault, http://comet.nerc.ac.uk/news_kashmir.html (2005).
2. A.J. Durrani, A.S. Elnashai, Y.M.A. Hashash and A. Masud, The Kashmir Earthquake of October 8, (2005), A Quick Look Report, Mid-America Earthquake Center, University of Illinois, Urbana-Champaign, USA (2005).
3. A. Hussain, Geology and Tectonics of Northern Pakistan with Respect to October 8, 2005, Earthquake, Presented at Earthquake Rehabilitation Conference, Seismology, Structures and Codes, Islamabad, 8-9 November (2005).
4. M. Ilyas, E-mail communication with M. Wieland, Chairman of the International Commission on Large Dams (ICOLD) Committee on Seismic Aspects of Dam Design (2005).
5. L. Seeber and J.G. Armbruster, in eds.: A. Farah and K.A. DeJong, Seismicity of the Hazara Arc in Northern Pakistan: Decollement *vs*. Basement Faulting, In: Geodynamics of Pakistan, Geological Survey of Pakistan, pp. 3-42 (1979).
6. www.http://internationalrivers.org/node/1283#pk-1.
7. http://en.wikipedia.org/wiki/Indus_River.
8. M.A. Mirza, M.Y. Khuhawar and R. Arain, *Asian J. Chem*., **19**, 5279 (2007).
9. http://www.ajk.gov.pk/main/index.html .
10. M.A. Mirza and M.Y. Khuhawar, *J. Sindh Univ. Res Sci. Series*, **38**, 25 (2006).
11. D.N. Wadia, *Mem. Geol. Surv. India*, **2**, 2 (1928).
12. M.N. Chaudhry and M. Ashraf, *Kash. J. Geol*., **2**, 1 (1984).
13. M. Ghazanfar and M.S. Baig, *Kash. J. Geol*., **1**, 1 (1983).
14. C.S. Meddlicott, *Rec. Geol. Surv. India*, **9**, 49 (1896).
15. I.A. Khan, M.A. Hashmi and H. Siddiqui, Proceedings of the 4th Pan Indian Ocean Science Congress, (PIOSC 16-24 Nov. 1960) Karachi, Pakistan, pp. 285 (1960).
16. M.A. Mirza, G.M. Arain and M.Y. Khuhawar, *J. Chem. Soc. Pak*., **28**, 430 (2006).
17. APHA Standard Methods for Examination of Water and Wastewater, American Public Health Association, Washington DC, edn. 17, p. 1497 (1989).
18. F. Anderson and B. Olsson, *Ecol. Bull*., **37**, 336 (1985).
19. W.T. Swank and D.A. Crossley, *Network*, **66**, 3 (1986).