Groundwater Contamination in District Nowshera, Khyber Pakhtunkhwa, In the Wake of Super-flood 2010

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Abstract: Khyber Pakhtunkhwa (KPK) was the most severely affected province in the monsoon flood of 2010. A total of twenty-seven water samples were collected, nearly two months after the flood, from Nowshera district and were analyzed for physical, chemical and biological parameters. Nearly all samples showed abnormally higher values for Electrical Conductivity (EC), hardness, alkalinity, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Total Solids (TS), Total Coliform Bacteria (TCB), Fecal Coliform Bacteria (FCB), chloride, sulfate, sodium, iron, lead, cadmium and nickel, therefore, water was not safe for human consumption. Some quality parameters, such as pH calcium, magnesium, nitrate, phosphate, chromium, copper and zinc, were found within permissible limits. This study was conducted to evaluate changes in the groundwater quality of district Nowshera in the wake of 2010 super-flood and to establish its relationship with wide occurrence of water-borne diseases.

Key words: Floods, Pakistan, Nowshera, KPK and water-borne diseases

INTRODUCTION

Pakistan received the most disastrous flood during 2010 monsoon, due to an extraordinary spell of heavy rainfall. One fifth of the country was flooded in the months of late July and early August (NDMA., 2011; Abid *et al.*, 2010). The catastrophic flood brought destruction; dislocation of community and millions of acres of fertile land was submerged. National Disaster Management Authority (NDMA), mentioned in its report that 78 districts were affected in whole country, of which 29 districts were severely affected. The Khyber Pakhtunkhwa (KP) was the most severely affected province in the whole country, where 24 districts were affected, while Peshawar, Charsadda, Nowshera, Swat, Dir, D.I. Khan, Shangla and Tank were the most brutally affected (Chitralli, 2010).

Flood brought many problems in the study areas, such as, unavailability of safe and hygienic drinking water, medical facilities, food, clothes and shelter. Moreover, the groundwater reservoirs were contaminated with many pathogenic organisms, due to inflow of flood water into groundwater through open wells and infiltration through soil. Local community of study area mainly depends on groundwater and drill water through hand pumps, bore and well. The contamination of groundwater reservoirs and stagnant water, after flood in

different districts, caused many water-related diseases, such as, cholera, dysentery, malaria and skin infection (Rehman, 2010).

MATERIALS AND METHODS

Study area: The study area is located along the banks of Kabul River with latitude from 33°-41' to 34°-10' N and longitude from 71°-30' to 72°-16' E. The district covers an area of 1,748 km², with 2342.5750 hectares agricultural land, 396.6400 hectares of shrub, bushes and 87.7347 hectares of forest (Ahmad, 2009). The study area has two main rivers, namely Kabul and Indus River. The district has two perennial streams, namely Kalpani River, Bara River and many dry streams or “Khawars” (Fig. 1), which are responsible for serious destruction in rainy season.

The climate of study area is pleasant, receives 50.8 mm and 18.2 mm of rainfall in the month of July and August, respectively, but in 2010, an unexpected rainfall was recorded, which was eight to twenty times more than the normal rainfall (Fig. 2). This unprecedented rainfall in the district was the main cause of catastrophic flood in the area (PMD., 2011).

Filed survey: An extensive field survey was conducted in the flood affected areas of district Nowshera in

Fig. 1: Location map of study area (Nowshera), Khyber Pakhtunkhwa, Pakistan

Fig. 2: Comparison of average rainfall in district Nowshera; from 2007-2010 (PMD., 2011)

October, 2010. During the field visit, interviews of the local communities and District Coordinator Officer (DCO) were conducted to assess the damage and destruction of property, agricultural land, groundwater quality and ensuing epidemics in the wake of super flood received in August, 2010. The data of water-borne

diseases was collected from WHO (World Health Organization), Peshawar.

Water sampling: Nearly two months after the flood, grab samples were collected from tube wells, dug wells and hand pumps of twenty-seven different villages and towns

Fig. 3: Points showing sample locations with respect to water sources

on either side of river Kabul (Fig. 3). On completion of laboratory analyses of all the samples collected in October, 2010, eleven sites were selected for the second phase of sampling, based on abnormally high values of certain parameters in October, 2011. Three sampling bottles, two polythene bottles of 500 mL (physical and chemical analyses) and one sterilized glass bottle of 250 mL (biological analyses) were filled from each sampling site. All samples were analyzed for pH, Electrical Conductivity (EC), Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Total Solids (TS), turbidity, alkalinity and hardness. Different cations (sodium, calcium, magnesium), anions (chloride, nitrate, sulfate, phosphate), heavy metals (iron, copper, nickel, zinc, lead, chromium, cadmium) and biological parameters (total coliform, fecal coliform) were also analyzed through standard procedures.

Analytical procedures: All the physical, chemical and biological parameters were analyzed, using standard methods (Arnold *et al.*, 1992). Some parameters, such as, pH and EC, were analyzed on the spot. pH was determined through Jenway 350 pH meter, EC and temperature were determined through water quality checker (U-10 Horiba, Japan). The TS, TDS, TSS, alkalinity and hardness were determined through titrimetric method. Anions (sulfate, nitrate, phosphate, chloride) were analyzed through HACH

spectrophotometer DR 2800 (Muhammad *et al.*, 2010; Islam ud Din, 2011), cations and heavy metals were determined through Perkin Elmer Analyzer 700 Atomic Absorption Spectrophotometer (AAS) (Muhammad *et al.*, 2011; Gul, 2011).

Statistical analysis: Microsoft excel software (Microsoft 2010) was used to graphically represent the results and to calculate the means and standard deviations of the results obtained.

RESULTS AND DISCUSSION

Table 1 and 2 summarize the status of physico-chemical parameters of samples, collected in October, 2010 and October, 2011, respectively. The results of heavy metals and coliform analyses of both phases of sampling are given in Table 3-4. The data of water-borne diseases collected from WHO (World Health Organization) are shown in Table 5.

Physico-chemical characteristic: In the study area, pH value ranged from 7.25-8.3 and 7.7-8.1 for samples collected in 2010 and 2011, respectively. Samples, collected in 2010, showed high values of EC ranging from 0.418-3.90 ms cm⁻¹, however, in 2011, most of the samples showed EC within the range from 0.40-1.50 ms cm⁻¹. During both phases (2010 and 2011),

Table 1: Physico-chemical water quality parameters collected from study area during 2010

Sample No.	Sample location	pH	EC (ms cm ⁻¹)	TSS (mg L ⁻¹)	TDS (mg L ⁻¹)	TS (mg L ⁻¹)	Hardness (mg L ⁻¹)	Alkalinity (mg L ⁻¹)	Cl (mg L ⁻¹)	NO ₃ (mg L ⁻¹)	SO ₄ (mg L ⁻¹)	PO ₄ (mg L ⁻¹)	Na (mg L ⁻¹)	Ca (mg L ⁻¹)	Mg (mg L ⁻¹)
1 a.	Tarru Jabba	7.37	1.295	400	350	750	934	1320	18.8	2	255	0.17	32.42	60.38	0.047
2	Bhalu	7.25	0.828	900	200	1100	879	980	13.5	1.9	90	0.36	10.24	51.03	1.077
3	Akbar Pura	7.29	1.066	100	650	750	1208	800	70.5	1.5	90	0.1	19.62	159.7	0.934
4	Khalikabad	7.45	0.75	250	350	600	703	930	17.7	2.8	23	0.11	9.6	48.71	0.142
5 a.	Teteray	7.72	1.598	150	1000	1150	835	1390	46.5	4.3	255	0.29	52.44	83.72	0.111
6	Tarkha	7.58	0.817	450	400	850	1002	1050	8.6	2.2	60	0.28	18.16	144	0.162
7 a.	Muhib Banda	7.66	1.630	300	750	1050	1274	1460	47.5	3.3	335	0.28	48.66	195.6	0.049
8 a.	Amankot	7.67	1.237	700	700	1400	1002	1000	39	0.4	235	0.19	27.52	77.75	0.392
9	Pabbi	7.77	0.915	650	250	900	597	900	11.5	0.6	110	0.31	23.46	35.24	1.473
10 a.	Pashonghari	7.84	0.852	950	600	1550	791	900	13.2	1.1	210	0.19	13.84	88.56	0.786
11	Aza Khel	7.57	0.820	150	500	650	756	1140	5.8	5.9	55	0.11	13.72	68.25	0.188
12	Pirpai	7.62	0.914	350	350	700	501	1020	11.3	6.8	80	0.57	16.9	23.02	0.063
13	Amangarh	7.59	0.420	5	395	400	492	520	3.8	10.9	10	0.15	3.8	16.41	0.927
14 a.	Nowshera Kalan	7.5	3.90	200	1200	1400	1012	1180	418	48	752	0.16	69	61.83	2.630
15 a.	Khatt Kalay	7.5	2.18	300	1100	1400	1327	850	157	2.4	650	0.21	61.66	64.91	2.142
16 a.	Choki Town	7.57	2.12	350	1050	1400	870	1050	286	5.3	335	0.13	67.94	156	1.151
17	Khesghi	7.78	0.434	150	200	350	360	430	2	6.4	36	0.11	8.06	20.5	0.094
18 a.	Faizabad	7.41	0.948	650	50	700	369	1250	5.4	0.7	40	0.19	35.94	21.84	0.035
19	Prisabaq	8.3	0.442	25	325	350	97	560	6.1	2.5	25	0.39	19.4	0.885	0.017
20	Nowshera cantt	7.82	0.857	5	545	550	703	650	19.8	4.6	150	0.27	15.2	42.45	0.129
21 a.	Hakimabad	7.3	1.221	300	650	950	844	930	110	45	170	0.22	30.48	70.25	1.415
22	Akora Khattak	7.79	0.890	700	100	800	677	580	34	22.6	97.5	0.3	16.46	25.34	0.062
23	Misri Banda	7.73	0.969	350	600	950	940	620	69	5.9	145	0.11	11.26	42.15	2.136
24 a.	Shaidu	8.1	0.418	20	280	300	422	492	2.2	7.1	158	0.41	5.66	24.63	0.098
25	Adamzai	7.42	0.924	550	400	950	835	900	22.7	23.1	90	0.38	12.14	32.54	0.288
26	Jhangira	7.59	0.935	50	800	850	659	580	18.6	1.4	66	1.56	17.98	31.44	0.184
27	Khairabad	7.52	0.685	50	550	250	633	550	20	4.3	97.5	0.16	9.98	27.76	0.181
Mean and St. Deviation		7.62 ±0.28	1.11 ± 0.70	335.5 ±271	533.1 ±299.4	853.7 ± 362.5	767.4±281	890 ±284	54.7 ±92.7	8.2±12.1	171.1±174.8	0.28±0.27	24.8±18.6	62±48.1	0.62±0.74

Table 2: Physico-chemical water quality parameters collected from study area during 2011

Sample No.	Sample location	pH	EC (ms cm ⁻¹)	TSS (mg L ⁻¹)	TDS (mg L ⁻¹)	TS (mg L ⁻¹)	Hardness (mg L ⁻¹)	Alkalinity (mg L ⁻¹)	Cl (mg L ⁻¹)	SO ₄ (mg L ⁻¹)
1b.	Tarru Jabba	7.7	1.18	2	666	668	650	700	7.3	245
5b.	Teteray	7.7	0.883	5	650	655	420	720	10.1	187.5
7b.	Muhib Banda	8.1	0.980	10	515	525	800	748	12.4	250
8b.	Amankot	7.7	0.848	20	680	700	735	525	7.5	187.5
10b.	Pashtonghari	8.1	0.55	100	1000	1100	450	475	10.2	180
14b.	Nowshera Kalan	7.8	1.50	50	1150	1200	750	450	230	450
15b.	Khatt Kalay	7.8	1.150	5	820	825	852	412	132	338
16b.	Choki Town	7.9	1.10	5	720	725	465	315	150	250
18b.	Faizabad	8.1	0.641	5	635	640	250	480	0	23
21b.	Hakimabad	7.8	0.70	3	747	750	425	525	35	165
24b.	Shaidu	8.1	0.40	5	245	250	315	250	2	140
Mean and St. deviation		7.8±0.2	0.90±0.32	10±8.4	693.4±208.5	703.4±213	555.6±207.9	509.1±160.6	54.2±78.8	219.6±110

Table 3: Heavy metals and biological water quality parameters collected from study area during 2010

Sample No.	Location	Fe (mg L ⁻¹)	Cu (mg L ⁻¹)	Ni (mg L ⁻¹)	Zn (mg L ⁻¹)	Pb (mg L ⁻¹)	Cr (mg L ⁻¹)	Cd (mg L ⁻¹)	Total coliform MPN/100 mL	Fecal coliform MPN/100 mL
1a.	Tarru Jabba	0.054	0.007	0.037	0.033	0.316	0.034	0.028	550	550
2	Bhalu	0.044	0.008	0.032	0.03	0.362	0.021	0.025	140	20
3	Akbar Pura	0.041	0.009	0.027	0.032	0.386	0.023	0.024	31	29
4	Khalikabad	0.033	0.006	0.011	0.049	0.468	0.028	0.023	550	550
5a.	Teteray	0.03	0.03	0.058	0.035	0.904	0.004	0.018	16	12
6	Tarkha	0.043	0.038	0.053	0.028	0.939	0.013	0.017	46	46
7a.	Muhib Banda	0.059	0.04	0.081	0.232	0.978	0.024	0.014	50	50
8a.	Amankot	0.232	0.044	0.055	0.044	0.998	0.024	0.013	1800+	250
9	Pabbi	0.023	0.047	0.069	0.053	1.039	0.026	0.018	1800+	1800+
10a.	Pashtonghari	0.18	0.001	0.058	0.145	1.067	0.015	0.014	2	0
11	Aza Khel	0.507	0.035	0.079	0.044	0.903	0.005	0.018	47	25
12	Pirpai	0.044	0.037	0.078	0.099	0.846	0	0.016	1600	1600
13	Amangarh	0.021	0.038	0.078	0.05	0.795	0.005	0.015	25	25
14a.	Nowshera Kalan	0.564	0.003	0.007	0.057	0.58	0.041	0.021	550	424
15a.	Khatt Kalay	0.644	0.041	0.031	0.188	1.1	0.029	0.018	17	17
16a.	Choki Town	0.047	0.05	0.039	0.323	1.132	0.018	0.018	22	9
17	Khesghi	0.468	0.033	0.082	0.038	1.134	0.03	0.01	4	4
18a.	Faizabad	0.062	0.016	0.01	0.119	0.471	0.028	0.016	29	29
19	Pirsabaq	0.013	0.015	0	0.045	0.495	0.035	0.013	14	12
20	Nowshera Cantt	0.017	0.033	0.079	0.175	1.123	0.028	0.01	14	4
21a.	Hakimabad	0.012	0.018	0.039	0.055	0.583	0.032	0.013	152	115
22	Akora Khattak	0.028	0.02	0.044	0.29	0.609	0.017	0.016	22	17
23	Misri Banda	0.045	0.017	0.048	0.29	0.686	0.004	0.01	29	12
24a.	Shaidu	0.066	0.023	0.062	0.861	0.707	0.012	0.01	31	8
25	Adamzai	0.031	0.035	0.053	0.034	0.788	0.001	0.012	7	4
26	Jehangira	0.04	0.029	0.07	0.077	0.753	0.001	0.012	9	2
27	Khairabad	0.127	0.03	0.069	0.048	0.781	0.003	0.013	0	0
Mean and St. deviation		0.128±0.18	0.026±0.23	0.04±0.02	0.128±0.16	0.77±0.25	0.018±0.012	0.016±0.004	-	-

Table 4: Heavy metals and biological water quality parameters collected from study area during 2011

Sample No.	Locations	Fe (mg L ⁻¹)	Ni (mg L ⁻¹)	Cd (mg L ⁻¹)	Pb (mg L ⁻¹)	Total coliform MPN/100 mL	Fecal coliform MPN/100 mL
1b.	Tarru Jabba	0.034	0	0.010	0.058	8	8
5b.	Teteray	0.012	0.001	0.001	0.017	7	0
7b.	Muhib Banda	0.011	0.001	0.003	0	16	2
8b.	Amankot	0.009	0.001	0.006	0.066	12	2
10b.	Pashtonghari	0.013	0.001	0.001	0.019	8	0
14b.	Nowshera Kalan	0.013	0	0.006	0.005	150	45
15b.	Khatt Kalay	0.012	0.001	0.003	0.057	7	2
16b.	Choki Town	0.022	0.001	0.010	0.008	20	0
18b.	Faizabad	0.007	0	0.010	0.039	7	0
21b.	Hakimabad	0.011	0	0.010	0.047	7	2
24b.	Shaidu	0.009	0	0.001	0.047	8	0
Mean and St. deviation		0.013±0.007	0.00054±0.00049	0.0055±0.003	0.033±0.03	-	-

Shaidu showed the lowest values and Nowshera Kalan showed the highest values of EC. In 2010, TSS calculated for most of the samples, which were above the permissible limit, ranging from 5-950 mg L⁻¹, only two sample locations, Nowshera Cantt. and Amangarh, showed TSS within safe limit. Conversely, most of the samples, collected in 2011, showed TSS within the safe limit, ranging from 2-100 mg L⁻¹. Sample collected

from Pahtonghari showed the highest value of TSS. Both TDS and TS for samples, collected during the first phase, were ranging from 50-1200 and 250-1550 mg L⁻¹, respectively. Though, the TDS and TS were found to be within permissible limits, ranging from 245-1150 and 250-1200 mg L⁻¹, respectively, for most of the samples collected after one year of first sampling.

Fig. 4: Comparison of electrical conductivity of water samples of 2010 and 2011

Table 5: Cases of water borne diseases in the study area after 2010 Super-flood

Locations	Cholera	Dysentery	Malaria	Skin infection	Total
Akbarpura	818	0	105	923	1846
Tarru Jabba	1382	0	116	1498	2996
Muhib Banda	299	1	41	340	681
Aman Kot	470	42	54	524	1090
Aza Khel	447	1	0	447	895
Kheshgi	370	3	0	370	743
Nowshera	1569	16	132	1701	3418
Pirsabaq	328	3	2	330	663
Misri Banda	413	0	115	528	1056
Akora Khattak	739	70	29	768	1606
Adamzai	468	26	80	548	1122
Shaidu	409	0	16	425	850
Jehangira	413	6	46	459	924
Khairabad	509	0	30	539	1078
Total	8634	168	766	9400	18968

The values of hardness of first phase samples, ranging from 360-1327 mg L⁻¹, the highest value (1327 mg L⁻¹) was observed for sample collected from Khatt Kalay and the lowest value (360 mg L⁻¹) for Kheshgi. The values of hardness changed in the second phase samples, varying from 315-852 mg L⁻¹, the lowest value (315 mg L⁻¹) was observed for Shaidu and the highest value (852 mg L⁻¹) was observed for Khatt Kalay. The samples, collected in 2010, showed higher values of alkalinity, ranging from 430-1460 mg L⁻¹. The highest value (1460 mg L⁻¹) was noted for Muhib Banda and the lowest value (430 mg L⁻¹) for Kheshgi. Teteray (1390 mg L⁻¹), Tarru Jabba (1320 mg L⁻¹), Aman Kot (1000 mg L⁻¹), Aza Khel (1140 mg L⁻¹), Nowshera Kalan (1180 mg L⁻¹), Choki Town (1050 mg L⁻¹) and Faizabad (1250 mg L⁻¹) showed abnormally high values of alkalinity. However, alkalinity values observed during the second phase of sampling, showed a remarkable decrease as values ranged from 250-748 mg L⁻¹. Relatively, higher alkalinity values were likewise

observed again for Muhib Banda (748 mg L⁻¹), Tarru Jabba (700 mg L⁻¹) and Teteray (720 mg L⁻¹), whereas, the lowest value was observed for Shaidu (250 mg L⁻¹).

Figure 4-5 show a comparison of different parameters of water samples, measured respectively, during 2010 and 2011.

All cations, such as, sodium, calcium and magnesium, analyzed during 2010, were found to be within the permissible limits, ranging from 3.8-69, 0.885-195.6 and 0.017-2.630 mg L⁻¹. Among the anions, nitrate and phosphate were within the permissible limits, ranging from 0.4-48 and 0.1-0.57 mg L⁻¹, respectively. However, the anions, such as, chloride and sulfate, were above the permissible limits (Fig. 6). The concentration of chloride ions for samples, collected in 2010, varied from 2-418 mg L⁻¹. Only two sample locations, namely Nowshera Kalan and Choki Town, showed higher values of chloride. However, samples, collected in 2011, showed normal concentration of chloride ranging from 0-230 mg L⁻¹. Samples, collected during first phase, showed concentration of sulfate ions ranging from 10-752 mg L⁻¹. Six sample locations, namely Tarru Jabba, Muhib Banda, Teteray, Khatt Kalay, Nowshera Kalan, Choki Town, showed the highest values of sulfate, while the rest of samples were within the permissible limits (Fig. 6). During the second phase, the concentration ranged from 23-450 mg L⁻¹, Nowshera Kalan and Khatt Kalay showed the highest values.

Heavy metals: Among the analyzed seven heavy metals (Table 3), zinc, copper and chromium were within safe limits. However, others, such as, iron, nickel, lead and cadmium, were above the permissible limits, during the

Fig. 5: Comparison of total hardness of water samples of 2010 and 2011

Fig. 6: Comparison of sulfate ions concentration in water samples of 2010 and 2011

first phase of sampling. The concentration of zinc, copper and chromium for samples, collected in 2010, ranged from 0.028-0.861, 0.001-0.047 and 0-0.041 mg L⁻¹, respectively. Concentration of iron in samples of 2010, ranged from 0.012-0.644 mg L⁻¹. Azakhel, Nowshera Kalan, Khatt Kalay and Khesghi showed higher values of iron. Moreover, all samples showed higher values of nickel, varying from 0-0.082 mg L⁻¹, except Nowshera Kalan and Faizabad. The situation changed in 2011, as all samples showed normal values of iron and nickel (from 0.007-0.034 and 0-0.001 mg L⁻¹, respectively). The concentration of cadmium was found to lie between 0.01-0.028 mg L⁻¹, in the first phase samples, almost at all sample locations, the concentration was above the permissible limits. Second phase samples showed the

values of cadmium, ranging between 0.001 and 0.010 mg L⁻¹, the lowest value (0.001 mg L⁻¹) was observed at Teteray and the highest value (0.01 mg L⁻¹) at Faizabad, Tarru Jabba, Choki Town and Hakimabad. The values of lead in samples, collected in 2010, were above the permissible limits, ranging 0.316-1.134 mg L⁻¹, while the concentration of lead, in second phase samples, was found to vary 0-0.066 mg L⁻¹.

Biological characteristics: Samples, collected in 2010 after two months of flood, were highly contaminated with TCB. Out of twenty-seven samples, only six samples were within the permissible limit of 10/100 mL set by WHO. The TCB observed in the study area, ranging from 0-1800, the highest number of TCB (1800) was noted for

Fig. 7: GIS based map showing locations and total number of cases water related diseases in district Nowshera due to 2010 flood

Aman Kot and Pabbi and the lowest number of TCB (0) was noted for Khairabad. Samples, collected from Pashtonghari, Kheshgi, Adamzai, Jehangira and Kairabad, showed the TCB within permissible limit. TCB in samples, collected in 2011, was ranged from 7-150, the highest value of TCB (150) was noted for Nowshera Kalan and the lowest number of TCB (7) was noted for Hakimabad, Teteray, Faizabad and Khatt Kalay. According to WHO drinking water standards, water having 0 FCB per 100 ml is safe for drinking. All samples, collected in 2010, were above the permissible limit except two points, in which FCB was not present. The FCB in samples, was ranged from 0-1800, water collected from Pabbi, was highly contaminated with 1800 and the samples, collected from Pashtonghari and Pabbi, was safe for drinking, because FCB was not detected. The values of FCB in samples, collected in 2011, ranged from 0-45. Samples from Teteray, Pashtomghari, Choki Town, Faizabad and Shaidu were safe for drinking, because FCB was not detected, while the highest number of FCB was observed in samples collected from Nowshera Kalan.

Water-borne diseases: Contaminations of drinking water, either directly or indirectly, by human or animal excreta, particularly feces and the use of such water for drinking, preparing food, contact during washing and

bathing, results in infection. Cholera, dysentery, gastroenteritis, hepatitis A, typhoid fever and poliomyelitis are some common water-borne diseases, caused by the contaminated and untreated water (Singh *et al.*, 2007).

As such, non-availability of safe drinking water and the lack of medical facilities in the wake of flood were the main causes of subsequent outbreak of water related diseases in the study area. A large number of cases of cholera (acute diarrhea), dysentery (bloody diarrhea), malaria, skin infection and conjunctivitis were widely reported from the affected local community.

The data, collected from the study area by WHO, suggests that 8,634 cases of cholera were recorded in six months after the flood with a majority of cases from Tarru Jabba, Akbarpura and Nowshera. A total of 178 cases of dysentery were reported from different villages of district Nowshera, including Akora Khattak, Jahangira, Adamzai, Pirpai, Aza Khel, Muhib Banda, Aman Kot, Nowshera and Kheshgi. Moreover, 766 cases of malaria were reported from the study area after the flood. Although, higher number of cases were reported from Tarru Jabba, Akbar Pura, Nowshera and Misri Banda. Almost, ten thousand cases (9,568) of skin infection were reported from district Nowshera after the flood of 2010. The highest number of cases were reported from Tarru Jabba and Nowshera (Fig. 7).

The results, obtained after different analytical procedures, showed that the concentration of some water quality parameters, such as, calcium, phosphate, magnesium, nitrate, zinc, chromium and copper, was within a permissible limit in samples, collected during the first phase. However, the pH was found to be within safe limit in all samples, collected during both phases, but the concentration of some parameters, including EC, alkalinity, hardness, TDS, TSS, TS, sulfate, iron, chloride, sodium, cadmium, lead, nickel, FCB and TCB, was above the permissible limit in 2010. Although, with the passage of time and infiltration of clean surface water in aquifers after flood, many of the water quality parameters of samples, collected in 2011, returned to their normal condition.

Nearly after two months of flood, water was highly contaminated and all samples showed a higher concentration of EC and TDS. In the first phase of sampling, the concentration of TS was high at some locations, namely, Bhalu, Teteray, Muhib Banda, Aman Kot, Pashtonghari, Nowshera Kalan, Khatt Kalay and Choki Town. However, TS was found within limits in samples collected during second phase after one year, except at Pashtonghari and Nowshera Kalan, which showed high values of TS.

Among the cations and anions nitrate, phosphate, calcium and magnesium were found within permissible limits, during the first phase of sampling. However, most of the samples showed higher values of chloride and sulfate, but after one year, the concentration of these parameters returned to normal, except for Nowshera Kalan and Khatt Kalay, which still showed higher values. In fresh water, high concentration of chloride is regarded as an indicator of pollution because of organic animal waste, inorganic fertilizers, irrigation drainage and industrial effluents (WHO., 1996). The existing data do not identify a level of sulfate in drinking water that is likely to cause adverse human health effects. The presence of sulfate in drinking water may cause dehydration and result in noticeable taste (WHO., 2004). Some of the heavy metals, like, zinc and copper, are essentially required for normal body-growth and functions of living organisms, while high concentration of other metals, like, cadmium, chromium and lead, is considered highly toxic to human (Ouyang *et al.*, 2002). Lead is highly toxic and carcinogenic metal and may cause chronic health risks, including headache, abdominal pain, blood pressure, kidney and lung damages (Steenland and Boffetta, 2000; Jarup, 2003). Iron is a vital component of hemoglobin, which helps red blood cells in carrying oxygen from lungs to body cells and, therefore, its deficiency causes anemia (Peter, 2000). Heavy intake of iron, through extraneous sources, causes nausea,

abdominal pain, constipation, intestinal infection and damages to liver and heart (Bhattacharjee, 2001). Cadmium occurs naturally in trace amounts in most foods and, at these levels, causes no harm to human health. Unlike some other metals, such as, copper and zinc, however, cadmium plays no role in human nutrition. Therefore, humans do not require cadmium in their diet and the unlikely event of anyone swallowing large amounts would probably result in unpleasant effects, such as, vomiting, diarrhea and even kidney damage (Barrento *et al.*, 2009).

The concentration of heavy metals including iron, nickel, lead and cadmium, was very high in 2010, but with time, the values changed.

In this study, samples, collected in 2010, were found highly contaminated with TCB and FCB. Although, five sample locations, namely, Tarru Jabba, Pashtonghari, Kheshgi, Jehangira and Khairabad, revealed safe water quality in terms of TCB, but samples from the remaining locations showed significantly polluted water, due to large number of total coliform bacteria in drinking water samples. Similarly, water quality of only two sampling sites, namely, Pashtonghari and Khairabad, was satisfactory from the perspective of fecal coliform bacteria, whereas, all other locations were found to be severely unsafe for human consumption. Subsequent sampling in 2011 revealed that out of 11 sampling sites selected for the second phase, 7 locations still showed unsafe water quality in terms of coliform bacteria.

Overall assessment of all the quality parameters indicates that although the whole of district Nowshera was severely affected by the flood with respect to its groundwater quality, but within one year, most parts of the study area returned to normal values except Nowshera, Pashtonghari, Tarru Jabba and Aman Kot, where almost all the parameters still indicate unsafe water and showed higher number of cases of water-borne diseases, because these locations are populated areas as compared to other locations of the study areas.

CONCLUSION

The super-flood caused intense damage and destruction to the infrastructure, livestock and population. Besides, the groundwater sources were also highly contaminated, due to infiltration of floodwater into the aquifer. Approximately, all physical, chemical and biological parameters of groundwater were found abnormally high and above the safe limits at all sample locations, rendering it unsuitable for human consumption.

Floodwater carried pathogenic organisms and contaminated groundwater with TCB and FCB, so, the local community faced consequences, including the wide

occurrence of water-borne diseases, like, cholera, dysentery, malaria and skin infection. One year later, the values of different water quality parameters returned to normal and within safe limits but certain locations, namely, Aman Kot, Nowshera, Pashtonghari and Tarru Jabba, still indicate contamination.

These results show that water becomes contaminated and unfit for the drinking purpose, so there is an urgent need for the arrangement of safe drinking water for the flood affected people. The proactive measures should be taken in regular flooded areas and policy regarding the management of area should be implemented strictly.

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