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Physiochemical Investigation of River Kabul at Michini, Khyber Pakhtunkhwa, Pakistan

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Abstract

The present study was conducted on River Kabul at Michini, Khyber Pakhtunkhwa, Pakistan from 25th June to 15th October 2011 in order to assess its water quality by studying its Physico-Chemical parameters. The studied physical and chemical parameters were falling in different ranges during the study period. The mean values for temperature (°C), pH, electrical conductivity (µS/cm), turbidity (NTU), total suspended solids (mg/l), total dissolved solids (mg/l), total solids (mg/l) and river depth (meters) were 18.44±2.46, 8.17±0.673, 212.62±47.299, 509.53±322.037, 1255.07±742.45, 136.13±30.25, 1391.19±714.124 and 1.91±0.645. The mean values for total hardness as $CaCO_3$ (mg/l), Calcium hardness as $CaCO_3$ (mg/l), Magnesium hardness as $CaCO_3$ (mg/l), total alkalinity (mg/l), Chloride (mg/l), Sodium (mg/l), Potassium (mg/l), Nitrite (mg/l), Nitrate (mg/l), Phosphate (mg/l), Ammonia (mg/l) and Sulfate (mg/l) were 138.93±14.004, 85.6±16.83, 53.6±11.79, 101.93±12.763, 12.99±5.675, 8.15±2.5, 4.98±0.85, 0.0557±0.0192, 3.03±0.91, 0.438±0.299, 0.458±0.21 and 80.94±16.49 respectively. All the physical parameters except total suspended solids and turbidity were falling in the safer range. Among the chemical parameters water hardness were slightly higher but were still falling within the suggested permissible limits of World Health Organization. Awareness should be created amongst the villagers residing on the banks to not use river banks as a disposal site for their sewage and garbage.

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Introduction

The most essential mater for life is water. Sustenance of life without food is for longer period as compare to water. But unfortunately on account of industrial revolution, the most important sources of water have been polluted and still being under deterioration (Ullah, 2015). The scenario of contamination is even more worsening when these sources pass through urbanized areas or cities (Ullah *et al.,* 2014a). All form of life need moderately clear and pure water otherwise they may not survive if their water have toxic chemicals in sever concentration (Deshpande and Aher, 2012).

One of the key sources of water supply is riverine system, all around the globe, which provide water for agriculture, drinking, industrial and many other purposes (Malik *et al.,* 2012; Ullah *et al.,* 2014b). But unfortunately this source has been polluted throughout the world and still under further contamination. At rivers' source, water use to pure relatively but it is contaminated on account of different reasons including its use, land use, urbanization, industrialization, agricultural runoffs, elevation in the use of chemicals, abstractive utilization of water, household use of chemicals like detergents and soaps etc. (Ullah *et al.,* 2014c). Water flowing downstream gathers salts, minerals and silt from rock and soil from bed of rivers. These are accompanied by other pollutants such as waste from animals, sewages, runoffs from agricultural fields and urban areas, effluents from industries and mining etc. (Ward and Elliot, 1995; Ullah, 2014). On account of the miss fortune, rivers face problems of pollution and contamination threats (Khan *et al.,* 2009). Sometimes these water bodies are polluted with wastes from humans and other animals, having pathogens, which may lead to different kind of epidemics or water borne diseases (Ullah and Zorriehzahra, 2014). Sometimes degradation of riverine water leads to different conflicts between upstream and downstream users.

Water from rivers have been employed for different purposes in different sectors of human development such as public water supply, aquaculture, transportation, industries, agriculture, cleaning and many other domestic purposes. Therefore owing to its multi uses, it has been felt as necessary to monitor water quality of river ecosystems all around the world in order to assess their capacity of production, potential of utility and for planning restorative and future measures (Das and Sinha, 1993).

River Kabul is one of the key riverine systems in Khyber Pakhtunkhwa, Pakistan. It is playing a very vital role for all masses living in the surroundings and adjoining areas. Due to sewages confluence, industrial activities and their resultant effluents having various organic compounds and metals, its water is under deterioration that may cause problems for human health and abiding aquatic organism. Contamination of the river is contributed by all factors such as individual households, factories, farms and urban areas. Owing to the scenario, the present study was conducted on River Kabul at Michini, Khyber Pakhtunkhwa, Pakistan in order to assess its water quality by studying its physico-chemical parameters.

Materials and methods

Water Sample Collection

Water samples were collected thrice a month from 25th June to 15th October, 2011 (a total of 12 samples for the study period). The samples were collected in clean plastic bottles of 2 litre capacity, thoroughly washed with tap water, followed by washing with river water. Three samples were collected, 10 cm below the surface, one from the centre of the river and the other two near the two banks and were mixed together to make one sample All the samples were collected between 09 am to 12 pm.

Water Analyses

Standard methods described in Standard Methods for the Examination of Water and Wastewater by the American Public Health Association (APHA/AWWA, 1998) were followed for the determination of' various physico-chemical water quality parameters. All the reagents used during water analyses were of analytical grade and freshly prepared.

Statistical Analysis

All statistical calculations were carried out using Microsoft Excel 2010.

Results and discussion

Table 1 and 2 are respectively showing sample wise values of physical and chemical parameters whereas Table 3 and 4 are showing month wise means values of physical and chemical parameters respectively. Figures 1-8 show physical parameters while Figures 9-20 reveal chemical parameters.

Table 1. Sample wise values of physical water quality parameters.

S.No	Parameters	JUNE	JULY			AUGUST			SEPTEMBER			OCTOBER	
		S 1	S 2	S 3	S 4	S 5	S 6	S 7	S 8	S 9	S 10	S 11	S 12
1	Status of bank	Stony	Stony	Stony	Stony	Stony	Stony	Stony	Stony	Muddy	Muddy	Muddy	Muddy
2	Colour of water	Muddy	Muddy	Muddy	Muddy	Muddy	Muddy	Muddy	Muddy	Slightly clear	clear	clear	clear
3	Depth (m)	2.30	2.35	2.20	2.40	2.45	2.40	2.50	1.80	1.55	1.30	1.00	0.90
4	Water temp (°C)	20.4	20.2	21	20.5	21.5	20	16	18	17.5	16	15.5	14.0
5	pH	8.21	8.04	8.27	8.29	8.10	8.30	8.30	8.18	8.32	8.01	8.05	8.07
6	T.S.S (mg/l)	1675	1650	1828	1778	1805	1850	1898	1400	760	463	201	45
7	T.D.S (mg/l)	125.1	138.5	107.6	102.7	141.7	104.0	105.6	122.7	108.5	168.9	184.9	192.6
8	T.S (mg/l)	1800.1	1788.5	1935.6	1880.7	1946.7	1954	2003.6	1522.7	868.5	631.9	358.9	237.6
9	E.C (μS/cm)	195.5	216.5	167.9	160.4	221.3	162.1	165.1	191.1	169.4	264	289	301
10	Turbidity (N.T.U)	755	760	683	704	768	752	686	485	235	170	65	25

Physical Parameters

Water temperature

Water temperature remained constant in months of June, July and August but declined in late summer. The mean value for water temperature was 18.44°C. In many fishes the stimulus for the start of spawning is a particular water temperature. The temperature in spawning grounds generally ranges from 23.8-30.5°C. High temperature damages the eggs and low temperature kills the spawn or drives the fish off the beds before spawning (Gupta and Gupta, 2006).

Khan and Khan (1997) reported water temp of 21°C at Michini, River Kabul. Water temperature reported at Michini in our study is within suitable range for warm water fishes.

Table 2. Sample wise values of chemical water quality parameters.

S.No	Parameters	JUNE	JULY			AUGUST			SEPTEMBER			OCTOBER	
		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
01	Total hardness as $CaCO_3$	132	148	128	124	130	128	120	144	120	160	156	168
02	Ca hardness as $CaCO_3$	60	87	83	81	87	80	83	87	92	112	108	100
03	Mg hardness $CaCO_3$	72	61	45	43	43	48	37	57	28	52	48	68
04	Total alkalinity (mg/l)	104	87	99	95	87	86	93	100	96	108	120	124
05	Chloride, Cl^- (mg/l)	6	20	16.5	21	7.7	9	10	12.6	10	16	16	20
06	Sodium, Na^+ (mg/l)	8.6	8.8	13.4	4.7	3.6	4.7	4.0	6.1	8.1	10.4	10.7	11.2
07	Potassium, K^+ (mg/l)	5.2	5.4	5.2	3.4	5.3	3.6	3.7	3.6	3.6	6.2	6.4	6.3
08	Nitrite, NO_2^- (mg/l)	0.027	0.046	0.063	0.069	0.066	0.042	0.035	0.071	0.115	0.040	0.036	0.103
09	Nitrate, NO_3^- (mg/l)	1.50	3.340	3.76	4.81	2.654	2.560	3.888	4.790	3.104	2.936	3.203	2.653
10	Phosphate, PO_4^{-3} (mg/l)	0.53	0.640	0.66	0.56	0.512	0.604	0.567	0.541	0.674	0.093	0.050	0.040
11	Ammonia, NH_3 (mg/l)	0.17	0.787	0.737	0.232	0.455	0.287	0.363	0.357	0.526	0.466	0.299	1.135
12	Sulfate, SO_4^{+2} (mg/l)	65.5	74.7	68.0	65.5	72.8	72.8	86.4	79.3	84.1	96.5	102.7	110.3

pH

The pH values remained relatively constant with highest value being 8.23 in August. The mean value for pH was 8.17. The pH of water decreased with increase in temperature. The pH of most natural waters falls in the range 6.0 to 9.0. The majority of natural waters have an alkaline pH due to the presence of carbonates and bicarbonates (Ali, 1993). The most suitable pH of water for aquaculture farmer is considered to lie between 6.5 - 8.5. Acid water (pH

5.0-5.5) can be harmful to eggs, fry and adults, acidity adversely effects the rate of decomposition of organic matter and inhibits nitrogen fixation, reduces the appetite, growth and tolerance of fish to toxic substance, toxicity of H_2S, copper and heavy metals is increased. Fishes are known to die at about pH 11 (Gupta and Gupta, 2006).

The pH values reported at Michini are within range set by World health organization, WHO for potable purposes.

Table 3. Month wise Physical Parameters of the collected samples of water.

S. No	Parameters	June	July	August	Sep	Oct	MEAN	SD
01	Status of bank	Stony	Stony	Stony	Muddy	Muddy	-	-
02	Colour of water	Muddy	Muddy	Muddy	Slighty Muddy	Clear	-	-
03	River depth (m)	2.30	2.32	2.45	1.55	0.95	1.91	0.64477
04	Water temp (°C)	20.40	20.60	19.20	17.20	14.80	18.44	2.4616
5	pH	8.21	8.20	8.23	8.17	8.06	8.17	0.6730
06	T.S.S (mg/l)	1675	1752	1851	874.33	123	1255.07	742.455
07	T.D.S (mg/l)	125.1	116.27	117.10	133.37	188.80	136.13	30.2488
08	T.S (mg/l)	1800.1	1868.27	1968.1	1007.7	311.75	1391.19	714.1241
09	E.C (µS/cm)	195.5	181.6	182.83	208.17	295	212.62	47.2996
10	Turbidity (N.T.U)	755	715.67	735.33	296.67	45	509.53	322.0374

Electrical Conductivity E.C (µS/cm)

Conductivity is a measure of water's ability to conduct electric current, which in turn depends upon the number of ions in water. The water sample whose E.C measurement is desired for limnological studies the temperature is adjusted at standard 25°C (Ali, 1993). The mean value for E.C was 212.62 µS/cm. A higher trend in E.C values was seen towards the later part of the year with maximum value being 295 µS/cm in October. It was observed that the values of E.C increased after the months of August whereas the values of turbidity and T.S.S decreased. Yousafzai *et al.* (2008) reported E.C values of 240 µS/cm during low flow (winter) and 172 µS/cm during high flow (summer) at Warsak Dam, River Kabul.

Turbidity

The mean value of Turbidity was 509.534 N.T.U. Maximum values of Turbidity were reported during high flow season (summer). During that period, the water volume and velocity is maximum carrying large amounts of sediment load and rendering the water turbid.

Table 4. Month wise values of chemical parameters of the collected samples of water.

S.No	Parameters	June	July	August	Sep	Oct	Mean	SD
01	Total Hardness as $CaCO_3$ (mg/l)	132	133.33	126	141.33	162	138.93	14.004
02	Ca hardness as $CaCO_3$ (mg/l)	60	83.67	83.33	97	104	85.6	16.8282
03	Mg hardness as $CaCO_3$ (mg/l)	72	49.67	42.67	45.67	58	53.6	11.7891
04	Total alkalinity (mg/l)	104	93.66	88.67	101.33	122	101.93	12.763
05	Chloride, Cl^- (mg/l)	6	19.17	8.91	12.87	18	12.99	5.6747
06	Sodium, Na^+ (mg/l)	8.6	8.9	4.1	8.2	10.95	8.15	2.5004
07	Potassium, K^+ (mg/l)	5.2	4.67	4.2	4.47	6.35	4.98	0.8499
08	Nitrite, NO_2^- (mg/l)	0.027	0.0593	0.0476	0.0753	0.0695	0.0557	0.0192
09	Nitrate, NO_3^- (mg/l)	1.590	3.970	3.034	3.610	2.928	3.0264	0.9088
10	Phosphate, PO_4^{-3} (mg/l)	0.53	0.620	0.561	0.436	0.045	0.4384	0.2997
11	Ammonia, NH_3 (mg/l)	0.170	0.585	0.368	0.449	0.717	0.4578	0.2087
12	Sulfate, SO_4^{+2} (mg/l)	65	69.4	77.17	86.63	106.50	80.94	16.4860

Water turbidity is caused either by a high content of solids such as clay particles or due to excessive production of Phytoplankton. Turbidity to some extent due to phytoplankton is an indicator of high fertility of pond but that caused by silt or mud is harmful to fish (Ali, 1993).

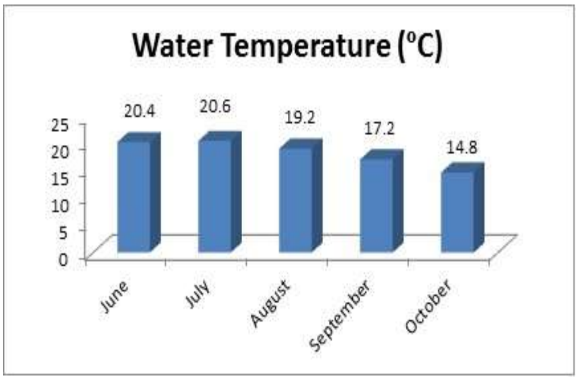

Fig. 1. Temperature of water during different months of sampling.

Studies on warm water fishes have shown that fishes did not show any behavioral reactions until the turbidity approached 20,000 ppm. Most of the experimental fishes are known to have tolerated turbidity higher than 100,000 ppm for a week but finally died at turbidities of 175000-225000 ppm due to gill clogging. Rivers with clayey bottom have high turbidity. All fish ponds attain the highest turbidity during rains (July-August). The excessive turbidity may effect directly, by killing fish through mechanical injury of their delicate gills or indirectly by reducing the natural food available in water (Gupta and Gupta, 2006).

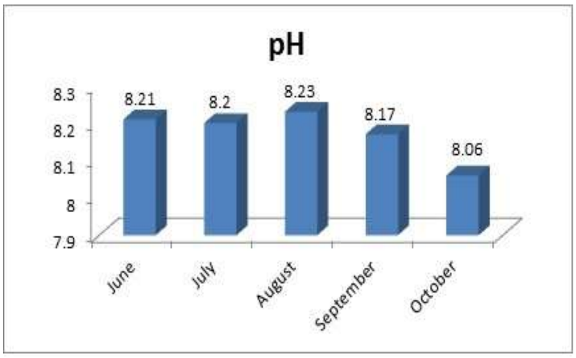

Fig. 2. pH of water during different months of sampling

Total suspended Solids

Suspended solids consist of silt, clay fine particles of organic and inorganic matter (Chapman, 1992). Mean value for T.S.S during our study was 1255.07 mg/l, with maximum value of 1851 mg/l recorded in August. During the months of June, July and August heavy monsoon rainfall and surface run off also adds to increased suspended load. Amjad (1996) studied Chitral and Bara rivers (tributaries of Kabul River) for suspended solids and found them most turbid with 1112 mg/l and 1125 mg/l values respectively. Values of total suspended solids reported at Michini exceed the limit set by W.H.O for potable water. However, water becomes much clearer during low flow and the value of TSS in winter falls within the limits set by W.H.O.

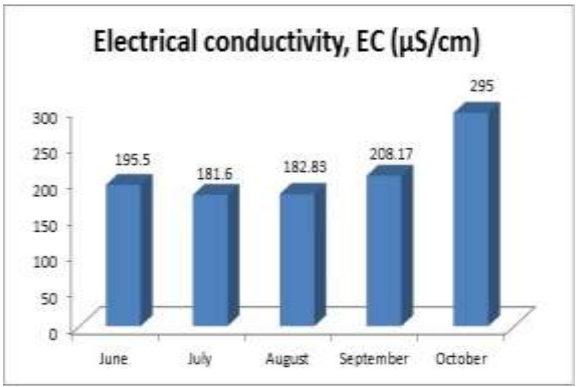

Fig. 3. EC of water during different months of sampling.

Suspended solids reduces the depth of light penetration decreasing primary productivity, kills fish by clogging their delicate gill filaments, destroy the spawning sites of many species of fish or prevent reproduction of fish by smothering eggs laid down on the bottom (Ali,1993).

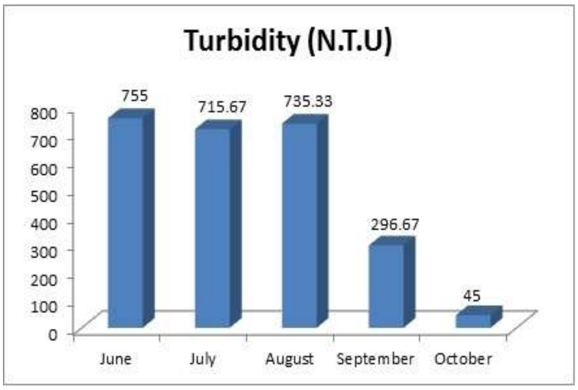

Fig. 4. Turbidity of water during different months of sampling

Total dissolved Solids (T.D.S)

Higher trend was seen in T.D.S values towards the later part of the year when the water level started to fall and the water became clearer. Maximum T.D.S value was recorded in October and it was 188.80 mg/l. The mean value for T.D.S was 136.13 mg/l.

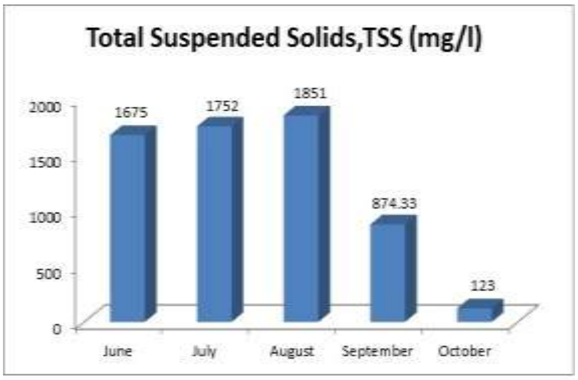

Fig. 5. Total Suspended Solids (TSS) of water during different months of sampling.

All natural water's contain dissolved solids. These dissolved solids largely consist of only a few salts, the carbonates, sulfates, chlorides of calcium, magnesium, sodium, potassium and small quantity of nitrogen and phosphorus compounds. In addition there are compounds of Iron and Manganese in very small quantities (Ali, 1993). T.D.S of natural waters varies from 15 to 1300 mg/l (Welch, 1952). TDS values reported here suggests that this water is suitable for drinking.

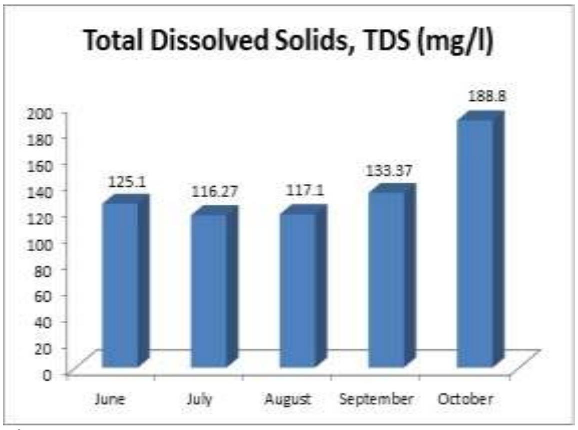

Fig. 6. Total Dissolved Solids (TDS) of water during different months of sampling.

Total Solids (TS)

Total solids were directly calculated using the formula T.S = T.S.S + T.D.S.

The maximum T.S value was 1968.1 mg/l in August with mean value of 1391.19 mg/l. Suspended solids proved to be the most dominant factor in determining T.S values. Suspended solids are a dominant feature of Kabul River which exists throughout its entire length during all seasons of the year (Nafees *et al.,* 2002).

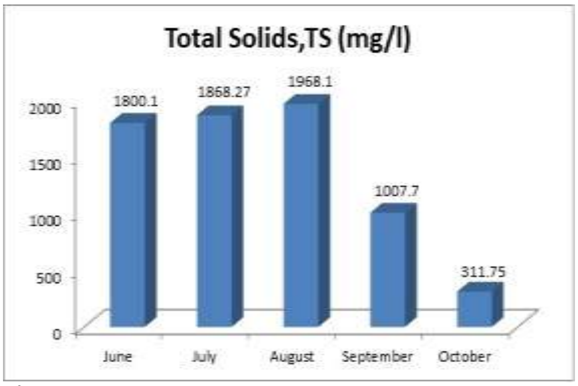

Fig. 7. Total Solids (TS) of water during different months of sampling.

River Depth

Maximum depth was recorded in August with a value of 2.45 meters. The mean value for river depth at the collection point was 1.91 meters, which is suitable for aquatic life. When the water is shallow, the sunlight penetrates up to the bottom, warms up the water and facilitates increased production. If the water is too deep, the bottom layers of ponds are less productive and gradually accumulate poisonous gases. Ponds less than one meter deep, gets overheated in tropical summers and may cause oxygen depletion. In general a depth of about 2.0 - 2.5 m is considered to be ideal from biological productivity point of view (Ali, 1993).

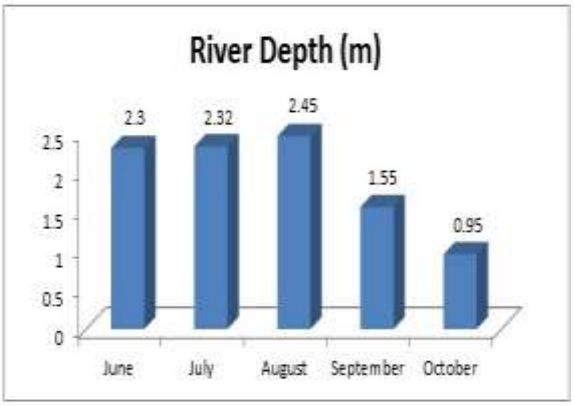

Fig. 8. River Depth of water during different months of sampling.

Chemical Parameters

Total Hardness as $CaCO_3$

Increase in values of total hardness was seen after the month of August with maximum value being 162 mg/l, reported in October. Mean value of total hardness for the study period was 138.93 mg/l. Yousafzai *et al.* (2008) reported total hardness values of 160.8 mg/l during low flow (winter) and 80.7 mg/l value during high flow (summer) at Warsak Dam. According to Wright and Welbourn (2002) based on hardness, 04 classes of fresh water can be recognized viz soft water (0-75 mg/l), moderately hard (75-150 mg/l) Hard (150-300 mg/l) and very hard (above 300 mg/l). Water of River Kabul is naturally hard (IUCN Pakistan, 1994). Hardness is the total soluble calcium (Ca) and magnesium (Mg) salts present in water and expressed as its calcium carbonate equivalent. Water with less than 5 mg/l $CaCO_3$ equivalent cause slow growth, distress and eventual death of fish (Gupta and Gupta, 2006). So, the total hardness values reported at Michini fall within W.H.O permissible limits.

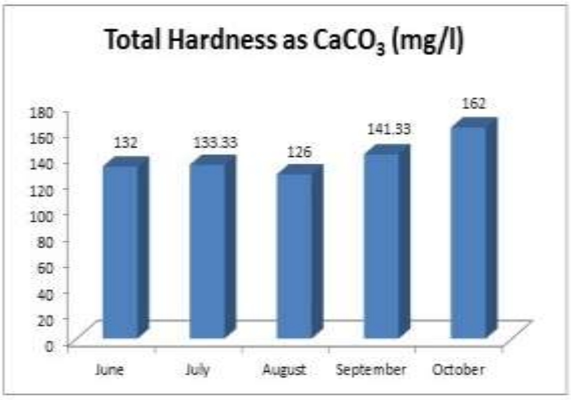

Fig. 9. Total Hardness of water during different months of sampling.

Calcium Hardness as $CaCO_3$

The maximum value for Ca hardness, reported during study period was 104 mg/l in October with mean value of 85.6 mg/l for the study period. Yousafzai *et al.* (2008) reported Ca hardness of 80.67 mg/l during low flow (winter) and 58 mg/l during high flow (summer) at Warsak Dam. Maximum limit set by W.H.O for Ca hardness for drinking water is 250 mg/l.

Magnesium Hardness as $CaCO_3$

Maximum value for Mg hardness was reported in June i.e. 72 mg/l, while the mean value for the study period was 53.6 mg/l. Yousafzai *et al.* (2008) reported Mg hardness value of 65.67 mg/l during low flow (winter) and 22.67 mg/l during high flow (summer) at Warsak Dam.

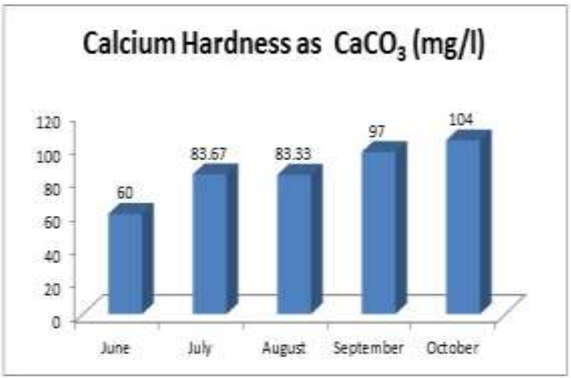

Fig. 10. Calcium Hardness of water during different months of sampling.

Maximum limit set by WHO for Mg hardness for Drinking water is 250 mg/l. Some salts of magnesium are toxic by ingestion or inhalation. Concentrations greater than 125 mg/l also can have a cathartic and diuretic effect (APHA/AWWA, 1998).

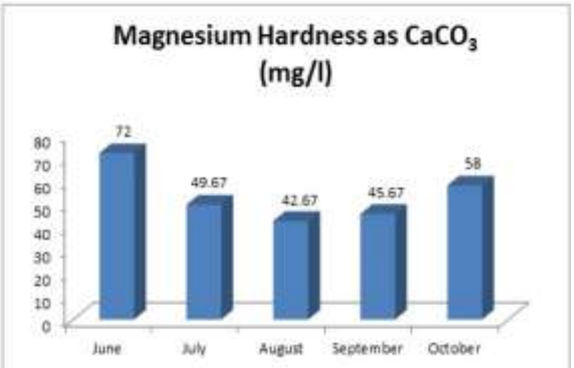

Fig. 11. Magnesium Hardness of water during different months of sampling.

Total Alkalinity

T. Alkalinity values increased after August. The maximum value reported was 122 mg/l in October. Mean value for T. Alkalinity was 101.93 mg/l. Yousafzai *et al.* (2008) reported T. alkalinity values of 73.2 mg/l during low flow (winter) and 58.67 mg/l during high flow (summer) at Warsak dam, River Kabul.

Alkalinity is important for fish and other aquatic life in fresh water ecosystem because it buffer pH changes that occur naturally as a result of photosynthetic activity. Components of Alkalinity such as carbonates and bicarbonates will complex some toxic heavy metals and reduce their toxicity (Nafees *et al.*, 2002).

Chloride (Cl^-)

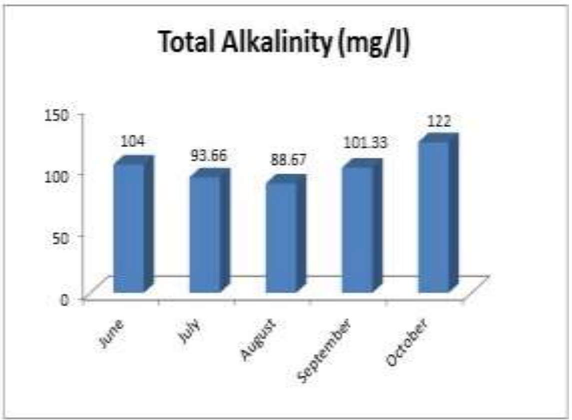

Fig. 12. Total Alkalinity of water during different months of sampling.

The mean value for chloride was 12.99 mg/l with value of 19.17 mg/l in July whereas minimum value of 6 mg/l in June.

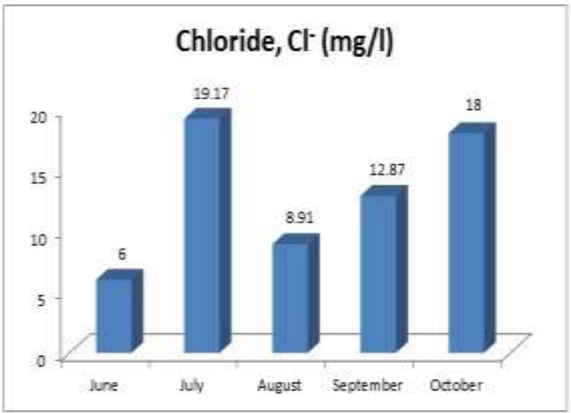

Fig. 13. Chloride of water during different months of sampling.

Yousafzai *et al.* (2008) reported Cl^- value of 7 mg/l during low flow (winter) and 5.67 mg/l during high flow (summer) at Warsak Dam on River Kabul. Khan and Khan (1997) reported Cl^- value of 12 mg/l in main Kabul River with 8 mg/l value at Michini Bridge. Maximum limits set by W.H.O for chloride content in potable water are 250 mg/l.

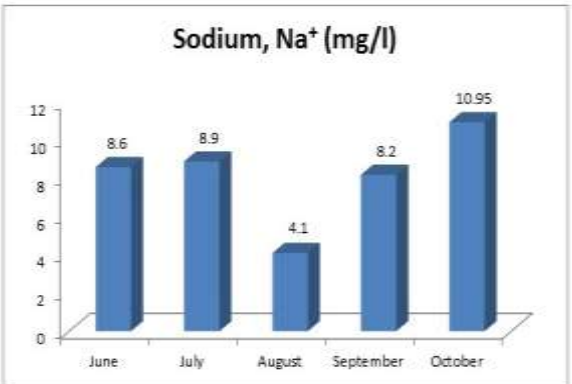

Fig. 14. Sodium of water during different months of sampling.

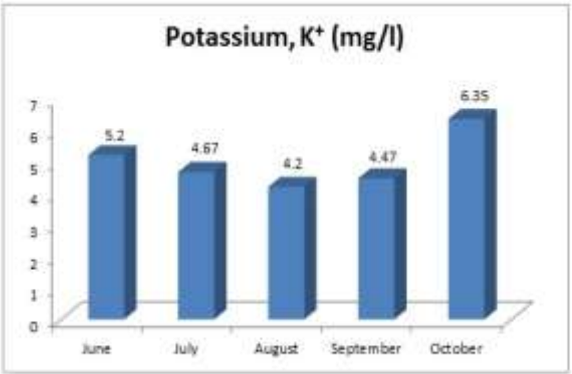

Fig. 15. Potassium of water during different months of sampling.

Sodium, Na

The mean value for sodium during the study period was 8.15 mg/l. Sodium values remained relatively constant with maximum value of 10.95 mg/l in October. A surprisingly low value was recorded as 4.1 mg/l in August. The U.S. EPA advisory limit for sodium in drinking water is 20 mg/l. So this water is safe for drinking.

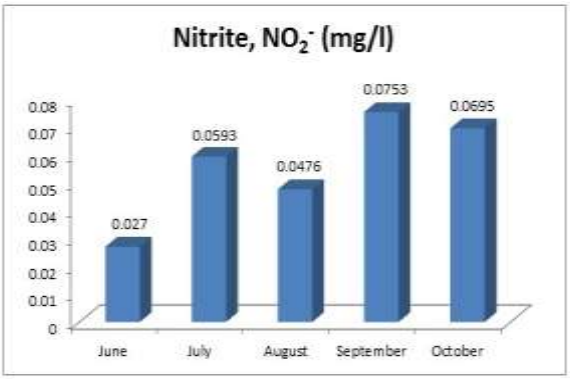

Fig. 16. Nitrite of water during different months of sampling.

Potassium, K

Potassium values remained constant with minor variations. Maximum value was reported in October as 6.35 mg/l. Mean value for potassium was 4.98 mg/l. Yousafzai *et al.* (2008) reported potassium value of 0.9 mg/l at Warsak Dam during low flow (winter) and 1.73 mg/l during high flow. Potassium is one of the most abundant elements in Earth's crust, of which it makes up 2.6 %. In natural water's potassium is found in less concentration than calcium, magnesium and sodium (Chhatwal *et al.*, 1989).

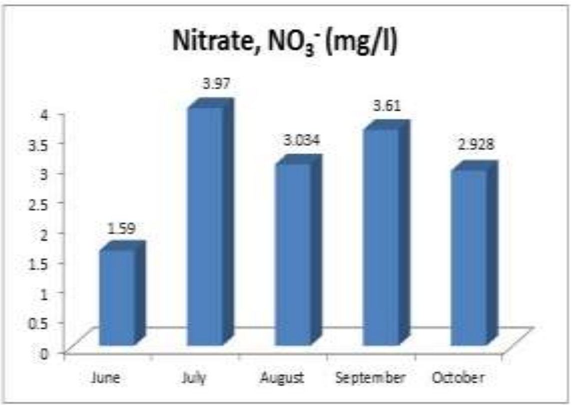

Fig. 17. Nitrate of water during different months of sampling.

Nitrite (NO_2^-)

Nitrite values fluctuated between 0.027 - 0.075 mg/l during the study period. The mean nitrite value for the study period was 0.056 mg/l. Khan and Khan (1997) reported 0.070 mg/l nitrite value in main Kabul River. The W.H.O limit for Nitrite in potable water is 0.01 mg/l so this water is safe for drinking.

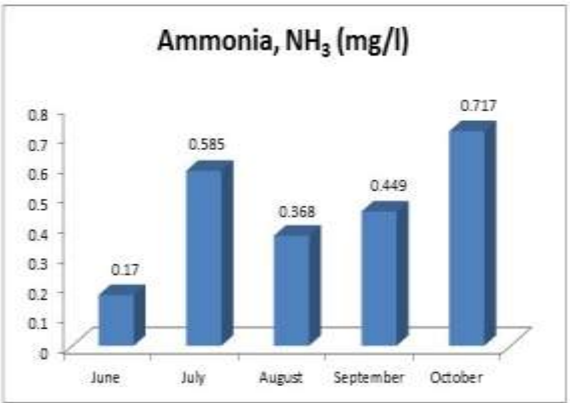

Fig. 18. Ammonia of water during different months of sampling.

Nitrites are usually present in very low concentration in fresh water of <0.001 mg/l and are rarely higher than 1 mg/l (Chapman, 1992). Ammonia may be oxidized in aerobic conditions to nitrite and eventually nitrate, which is significantly less toxic to aquatic life (Chapman, 1992). In humans, methaemoglobinaemia is a consequence of the reaction of nitrite with haemoglobin in the red blood cells to form methaemoglobin, which binds oxygen tightly and does not release it, thus blocking oxygen transport. High levels of methaemoglobin (greater than 10%) formation in infants can give rise to cyanosis, referred to as blue baby syndrome (WHO, 2011).

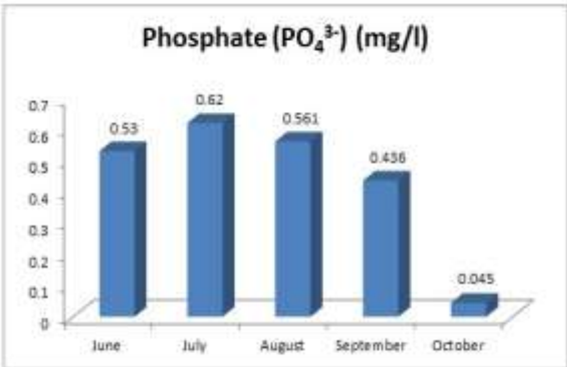

Fig. 19. Phosphate of water during different months of sampling.

Nitrate (NO_3^-)

Maximum nitrate value reported was 3.970 mg/l. Mean value for the study period was 3.0264 mg/l, which is within the safe limits of 45 mg/l level set by WHO for potable water. Yousafzai *et al.* (2008) reported nitrate values of 1.07 and 1.82 mg/l at Warsak Dam during low flow and high flow season respectively. Nitrates are always contributed by human activities in the form of domestic sewage and use of fertilizers (Xue *et al.*, 2009). Nitrate is an important plant nutrient when it is present in excess it tends to stimulate algal growth and indicates possible eutrophic condition (Chatawal *et al.*, 1989; Chapman 1992 in Nafees *et al.*, 2002). Nitrate concentration over 30 (mg/l) can inhibit growth, impair the immune system and cause stress in some aquatic species (Petrucio and Esteves, 2000).

Ammonia (NH_3)

Ammonia values remained high after June, with minimum of 0.170 mg/l in June and maximum of 0.717 mg/l in October. Mean value for study period was 0.457 mg/l. Yousafzai *et al.* (2008) reported 0.0018 mg/l and 0.01 mg/l ammonia concentration at Warsak Dam during low flow and high flow respectively. Ammonia in water is an indicator of possible bacterial, sewage and animal waste pollution (WHO, 2011). High concentrations of ammonia are toxic to aquatic life (Chapman and Kimstach, 1996). Ammonia is extremely toxic to fish and should be present at levels which are ideally below 0.02 mg/l values above 2.0 mg/l total ammonia are usually an indication of serious organic pollution (Chapman, 1992). Ammonium ion (NH_4) is far less toxic to the fish as compared to free ammonia. At low pH, ammonia is more likely to appear as less toxic ammonium. It means that ammonia levels are more toxic in water having high pH level. Temperature also effects ammonia toxicity, high temperature cause more free ammonia to be released into the water (Hiscock, 2000).

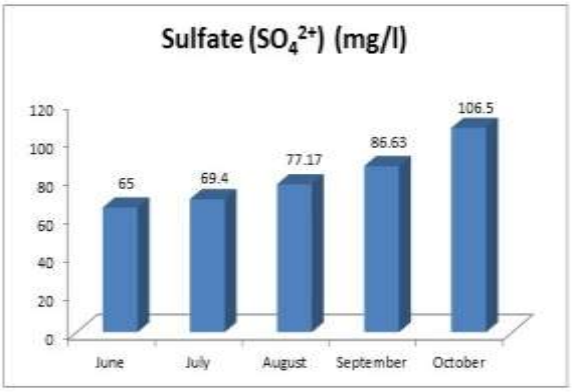

Fig. 20. Sulfate of water during different months of sampling.

Phosphate

Phosphate values reported at Michini were ranged between 0.4 to 0.6 mg/l, with a sudden decrease in October where the lowest value of study period 0.045 mg/l was reported. Mean value for phosphate was 0.038 mg/l. Yousafzai *et al.* (2008) reported 0.07 mg/l and 0.08 mg/l Phosphate values at Warsak Dam during low flow (winter) and high flow (summer) respectively. Phosphate value of 0.30 mg/l was reported by Khan and Khan (1997) in main Kabul River however phosphate was not detected at Michini Bridge.

Sulfate (SO_4^{2-})

Month wise ascending order was seen in sulfate values throughout the study period. Minimum sulfate value recorded was 65 mg/l in June and maximum value of 106.5 mg/l was recorded in October. Mean value of sulfate for the study period was 80.94 mg/l. Sulfates are discharged into water in industrial wastes and through atmospheric deposition; however, the highest levels usually occur in groundwater and are from natural sources. The WHO maximum limit for sulphate in drinking water is 500 mg/l, so the sulphate value reported here suggests that this water is potable (WHO, 2011).

Conclusion

All the physical parameters except total suspended solids and turbidity were falling in the safer range. Among the chemical parameters water hardness were slightly higher but still falling within the suggested permissible limits of World Health Organization. Awareness should be created amongst the villagers residing on the banks of River Kabul not to dispose off their sewage and garbage in the river and its banks.

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