SEASONAL VARIATION IN WATER QUALITY OF LOWER SINDH, PAKISTAN

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Abstract

A comparative study on water quality has been carried out in pre- monsoon and post -monsoon seasons of district Thatta, lower Sindh. The water samples were analyzed for physical, chemical and microbiological parameters by the methods described in the Standard Methods for the Examination of Water and Wastewater (APHA, 2005). Temperature ranged between 24-33^{0}C, pH varied between 6.9-8.9 and Electrical conductivity was between 233-987µScm^{-1}during pre- and post-monsoon seasons respectively. Total dissolved solids (TDS) 161.1-690.9ppm, Total hardness ranged between124.40-188.81ppm as $CaCO_3$. Chloride content was observed between 81.79-131.78 ppm while the range of nitrate was between 2.10-5.20ppm.The concentrations of the heavy metals were found to be in order Pb > Cu > Cd > Zn > As in pre-monsoon and Pb> Cd > Cu > Zn > As in post- monsoon respectively. It was observed that water available in the district is non-potableand unsafe for human consumption and contaminated with human or animal waste.

Introduction

The physical, chemical and biological quality of drinking water is controlled by naturaland anthropogenic factors (domestic, industrial activities and agricultural run-off). Increasing water pollution not only deteriorates water quality, but also contributes to public health problems, economic stress and social disprosperity (Milovanovic, 2007; Pandey *et al.*, 2007; Kupwade *et al.*, 2013) .

District Thatta, is situated at 23º 43' to 25º 26' and 67º 05' to 68º 45' in Sindh province of Pakistan. The district has unique geographical boundaries, from northwest with Jamshoro district (agricultural), on the east by Hyderabad and Badin districts (agricultural), on the south by the Arabian Sea and Run of Kachh (desert) and on the west by industrial hub Karachi. Thatta district comprises of nine sub-districts, out of which four are situated on right and left bank of River Indus while one sub-district Kharochan is situated on both sides of River Indus. The southwest part of the district has a coastline of about 107 kilometers.

Thatta is one of the poorest district of Pakistan. The water in the district is of variable quality and is one of the major threats to public health. It is non-saline near sources of recharge, i.e., rivers and canals but gradually becomes saline and sea–affected near the coastline and as depth from the recharge source increases (Mashadi and Mohammad, 2000; Bhutta *et al*. 2002). Deprivation in water quality is also due to large scale withdrawal of groundwater resulting in lateral and vertical movement of saline water into fresh water zones.The contamination of fresh water with saline water leads to a number of aliments including diarrhea, vomiting, gastroenteritis, kidney disease and skin problems (Memon *et al*., 2011). Several studies also reported that water qualityparameters do not meettheWHO/Pakistan standards (Rahman,1996; Chilton *et al*., 2001; Malana and Khosa, 2011; Farid *et al*., 2012; Khan *et al*., 2012a).

Very few studies have been conducted and limited data is available about the quality of water resources in the area. By considering the above facts a comprehensive study has been designed to investigate the seasonal physicochemical, microbiological andmetallic parameters of water in Thatta district. It is imperative to prevent and control the surface water pollution and to have reliable information on its quality for effective management so as to protect the consequent deleterious effects on human health and eco system.

Materials and Methods

Collection of Samples: Water samples were collected fromthirty nine pre designated location from Thatta districtduring pre-monsoon (April-May) and Post-monsoonperiod (July-Sep) in 2012. The water samples were collected in two liters presterilizedglass bottles. The bottle was carefully filled to avoid trapping air bubbles. The samples were sealed having specific codes, labeled and transported to the Institute of Environmental Studies laboratoryin refrigerated condition.

Physico-Chemical parameters: The Water samples were analyzed for temperature, pH, Dissolved oxygen, Total dissolved solids, electrical conductivity and turbidity.Chemical parameter Biochemical Oxygen Demand (BOD_5) was measured using azide modification method while COD (chemical oxygen demand) was ascertainedby dichromate reflux method using HACH COD reactor (APHA, 2005).Phosphate was estimated by ammonium molybdate and ascorbic acid method (APHA, 2005). Chloride was estimated by Argentometric method as described in (APHA, 2005). Nitrate concentration was determined by Bruccine Sulfanalic acid method while calcium, magnesium andtotal Hardness of water samples was measured by EDTA titrimetric method as described inAPHA (2005).Sulphate was measured by gravimetric method described in Standard Methods for the Examination of Water and Wastewater (APHA, 2005). Sodium and potassium ions were determined using flame photometry as described in (APHA, 2005). pH, turbidity and electrical conductivity (EC) were measured on site. pH was by determined by Hanna portable pH meter (HI98107), while DO and electrical conductivity were measured by DO meter (Jenway, 970). Turbidity was determined by EUTECH meter, Model No. TN-100. TDS and TSS were ascertained by gravimetric method as given in (APHA, 2005).

Heavy metal analysis: The water samples were analyzed for heavy metals including As, Cr, Cu, Pb, Ni and Zn. The above mentioned parameters were analyzed using appropriate kits of Merck NOVA 60 (Germany).

Bacteriological analysis: The bacteriological examination of water samples was assessed for total coliforms count (TCC) and Total Faecal coliforms (TFC). The samples were processed in a laminar flow hood using sterilized culture media. The bacterial load of water samples was estimated by Most Probable Number (MPN) technique as per Standard Methods for the Examination of Water and Wastewater (APHA, 2005)

Results and Discussion

The water samples collected during pre and post monsoon periodwere analyzed through physico-chemical and microbiological analyses. All thirty nine samples were collected from Thatta district in the year 2012. Table 2, 3 and 4 shows descriptive statistics of physical, chemical and microbiological parameters, respectively while Table 4 shows the concentration of heavy metals in water samples.

The physical analysis of water samples revealed that the samples collected from different location are aesthetically acceptable from consumer viewpoint. According to WHO standard, there should be no color, odor or taste in drinking water (PCRWR, 2005; WHO, 2006; NSDWQ, 2008). The physical parameters are within the permissible limits as per WHO guidelines and NSDWQ (2008).

Water temperature of the samples at source ranged from 26.0°C to 33°C in the two seasons. High temperature in pre-monsoon season is due to increase in ambient temperature.Higher temperature influences other factors including pH, conductivity, dissolved gases and alkalinity,therebyit is responsible for deterioration of aesthetic quality of drinking water (WHO, 2006; Farha et al., 2013).

The pHof water indicates the extent of acidity or basicity of water.The results shows that the water samples were slightly acidic to moderately alkaline (6.9- 8.9) and (6.8-8.2) in both the seasons and within the permissible limit (pH 6.5-8.5) of drinking water standards of WHO, (2006). Comparatively higher pH value was observed during post-monsoon period which could be due to dilution of water as a result of precipitation. The results are in accordance with Carr and Neary, (2008), Memon *et.al.*(2011).

Electrical conductivity (EC) of water is an index to represent the total concentration of soluble salts in water(Harilal *et al*., 2004). The reference value of electrical conductance for drinkingwater set by WHO is 1200µS/cm^2 (WHO, 1996).The values of Electrical conductivity (EC) varied in the range (101.9-166.9µS/cm^2) in pre monsoon and (101.8-125.7µS/cm^2) in post monsoon. The lower EC values in post monsoon season may be attributed to dilution factor as a result of high flow of water due to excessive rain. These results were in accordance with the results those reported by Iqbal, *et al.* (1996).

Turbidity inwater is usually due to colloidal and fine suspended particles. Turbidity values of water samples ranged from (5.1-5.5NTU) and (6.9 -8.7 NTU), respectively in both seasons. Water samples were relatively turbid in post monsoon season. This could be due to erosion of banks and high flow rate as compared to pre-monsoon season. The values observed are in conformity with the results reported by Garg *et al.* (2006b).

Total Hardness as ($CaCO_3$) represents the presence of calcium, magnesium, bicarbonate and sulfates in water. Hardness values of the water samples varied from (155-188mg/L)and (117-150mg/L) in pre and post-monsoon respectively.(WHO, 2011) and (PCRWR, 2005) recommended safe permissible limit for hardness is 500 mg/l. The contamination of hardness more than 500mg/lin water has adverse effects on human health and may cause heart disease and formation of kidney stones (Memon *et al.* 2011). The concentration observed during the study are in conformity with the result reported by Lalitha and Barani (2004).

Total dissolved solids represent the amount of inorganic substances in the water that originates from natural sources, sewage, industrial waste and chemicals used for water treatment process.The high amount of dissolved, suspended and total solids prevalent in the samples adversely affect the quality of water rendering it unsuitable for drinking purpose. The maximum permissible limit for TDS in drinking water as per WHO guidelines is 1000 mg/L. TDS concentration varied from (699 to 834mg/L) in the pre -monsoon and from (505mg/L-709mg/L)inpost -monsoon which are within permissible limit set by WHO.TDS values weremuch higher during pre-monsoon season which is influenced by low hydrological flow and also by physical factors such as evaporation.

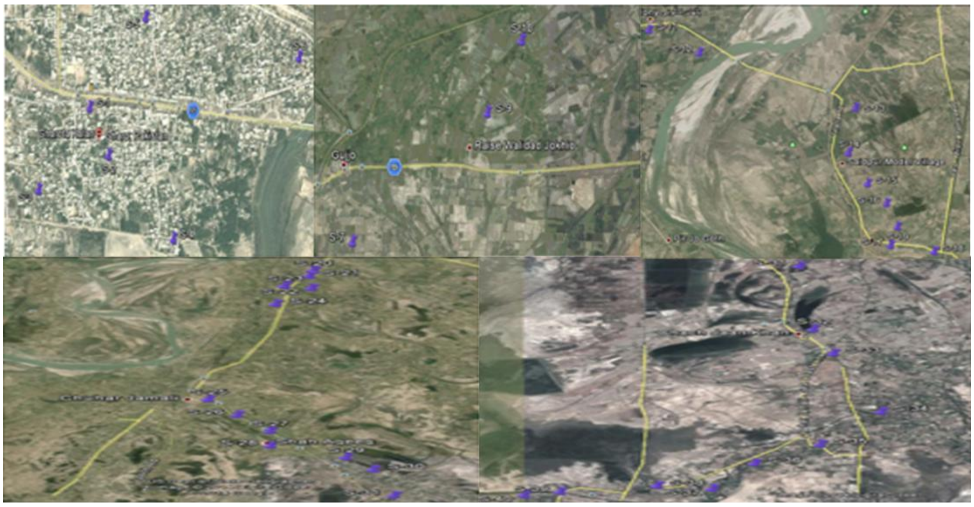

Fig. 1. Sample site of study area.

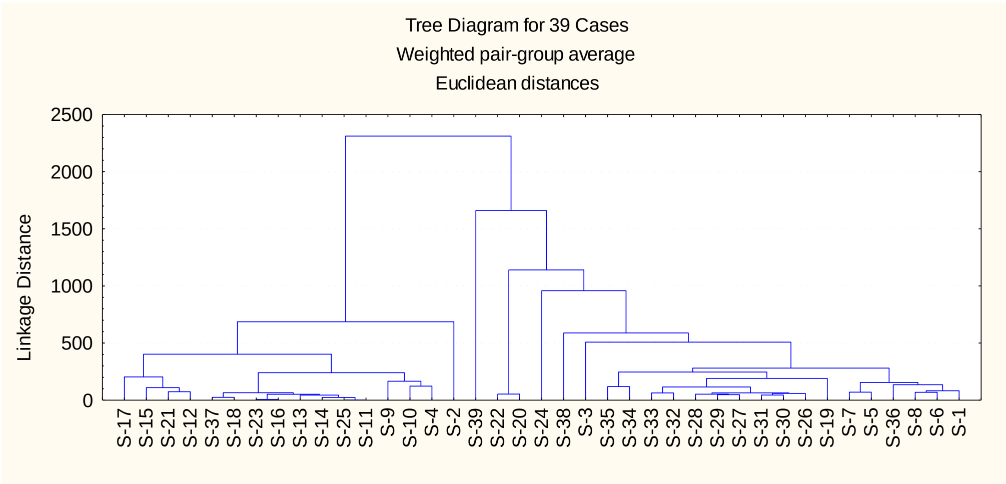

Fig.2. Dendogram derived from weighted pair-group method of 39 sites based on physical, chemical and bacteriological quality of water of Lower Sindh, District Thatta during Pre-monsoon.

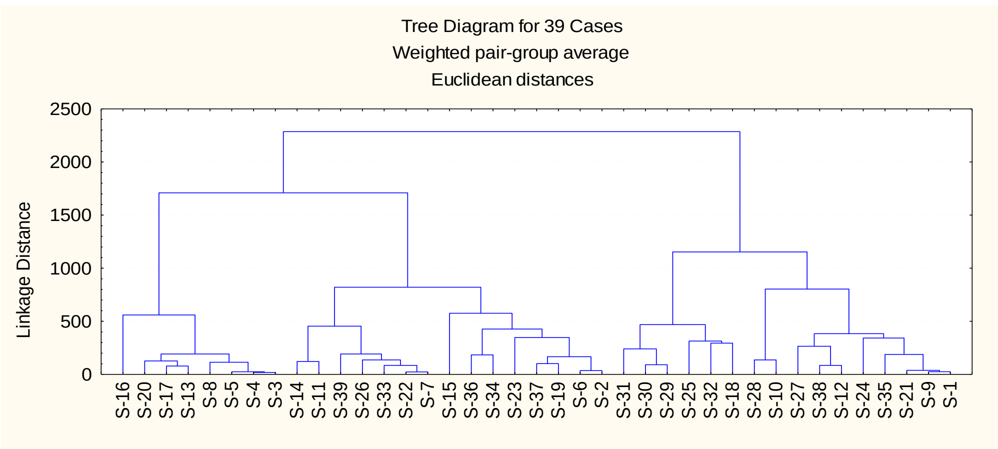

Fig.3. Dendogram derived from weighted pair-group method of 39 sites based on physical, chemical and bacteriological quality of water of Lower Sindh, District Thatta during Post-monsoon.

Table 1.Sampling coordinate of different localities of district Thatta.

Sample	**Sampling location**	**GIS Coordinate**
S-1	Gharo	24°44'26.85"N, 67°35'1.79"E
S-2	Gharo	24°44'22.38"N, 67°35'4.43"E
S-3	Gharo	24°44'19.16"N, 67°34'54.66"E
S-4	Gharo	24°44'14.61"N, 67°35'13.40"E
S-5	Gharo	24°44'35.20"N, 67°35'9.55"E
S-6	Gharo	24°44'31.49"N, 67°35'30.81"E
S-7	Gujjo	24°43'44.84"N, 67°46'15.97"E
S-8	Gujjo	24°43'13.67"N, 67°45'15.81"E
S-9	Near RaeesWalidadJokhio, Gujjo	24°45'0.37"N,67°47'59.74"E
S-10	Adjacent to canal road,Gujjo	24°45'42.58"N, 67°48'25.94"E
S-11	Near Thatta-Sujawal bridge, opposite to pathan colony	24°41'37.40"N,67°57'12.31"E
S-12	Near Thatta-Sujawal bridge, close to Indus delta	24°41'7.93"N, 67°58'12.88"E
S-13	Thatta – Sajawal road	24°39'56.32"N, 68° 1'19.89"E
S-14	Saidpur model village	24°38'58.21"N, 68° 1'11.19"E
S-15	Saeedpur Old	24°38'18.53"N, 68° 1'33.98"E
S-16	Saeedpur Old	24°37'53.05"N,68° 1'56.59"E
S-17	Saeedpur New	24°36'59.04"N, 68° 2'1.13"E
S-18	Saeedpur New near canal road	24°36'50.63"N, 68° 2'53.51"E
S-19	Saeedpur New	24°37'22.67"N, 68° 2'9.57"E
S-20	Sajawal- ChuharJamali Road	24°32'13.26"N,68° 3'6.91"E
S-21	Sajawal- ChuharJamali Road	24°31'51.44"N,68° 2'59.66"E
S-22	Sajawal- ChuharJamali Road	24°31'1.95"N, 68° 3'3.65"E
S-23	Sajawal- ChuharJamali Road	24°31'10.99"N, 68° 2'15.68"E
S-24	Mohammad Rahim Shah,	24°29'56.28"N,68° 1'59.23"E
S-25	ChuharJamali	24°23'26.07"N, 67°59'57.27"E
S-26	Chuharjamali -Sea coast link road	24°22'22.08"N, 68° 0'48.92"E
S-27	Chuharjamali -Sea coast link road	24°21'15.97"N, 68° 1'47.13"E
S-28	Chuharjamali -Sea coast link road	24°20'15.57"N, 68° 1'47.94"E
S-29	Ladhion Village, Shah Bander	24°19'27.91"N,68° 4'2.54"E
S-30	Ladhion Village Shah Bander	24°18'37.68"N, 68° 4'51.53"E
S-31	Between Ladhion and ChachJahan	24°16'50.69"N, 68° 5'28.02"E
S-32	ChachJahan, Shah Bander	24°15'5.65"N, 68° 5'39.24"E
S-33	Shah Bander Village	24°14'25.44"N, 68° 5'56.01"E
S-34	Shah Bandergoth	24°12'48.64"N,68° 6'36.04"E
S-35	Shah Bander	24°11'54.34"N, 68° 5'44.53"E
S-36	Shah Bander near coastal area	24°11'23.04"N, 68° 4'49.11"E
S-37	Shah Bander near coastal area	24°10'40.92"N,68° 4'13.30"E
S-38	Shah Bander close to Creeks	24°10'45.83"N, 68° 3'26.76"E
S-39	Shah Bander close to Jeti	24°10'35.76"N, 68° 2'5.26"E

Table 2. Descriptive statistics of physical, chemical parameters of water samples during pre monsoon season.

Variable	Mean	Median	Min	Max	Lower Quartile	Upper Quartile	StdDev	SE
Temp	28.86	28.5	26	33	26.2	30.5	2.46	0.44
pH	7.61	7.6	6.9	8.9	7.2	8.1	0.46	0.08
Ca (ppm)	83.90	83.8	69.9	91.4	81.7	88.7	5.25	0.94
Mg(ppm)	83.19	83.6	80.1	103.7	81.2	86.3	13.59	2.44
Na(ppm)	60.92	65.7	44.2	69.3	52.9	68.1	8.67	1.55
K(ppm	6.70	7.3	4.8	7.9	5.3	7.6	1.11	0.20
Cl(ppm)	142.56	150	105	170	122	159	22.08	3.96
SO_4(ppm)	138.67	146	95.4	161	126	152	17.05	3.06
HCO3(ppm)	189.41	190	181	199	184	194	5.66	1.01
TDS(mg/L)	789.06	819	699	834	725	829	51.84	9.31
Turbidity (NTU)	7.27	7.3	5.1	8.7	6.1	8.4	1.18	0.213
TSS(mg/L)	172.35	170	160	220	148	200	33.04	5.93
BOD_5(mg/L)	76.71	80	60	110	60	90	21.73	3.90
COD(mg/L)	80.48	80	50	100	70	90	12.10	2.17
Conductivity(mv)	1564	1638	1019	1669	1457	1665	166.27	29.86
NO_3(ppm)	12.26	12.7	10.2	13.0	12.1	12.9	1.28	0.23
PO4(ppm)	11.30	13.5	2.1	11.3	3.1	16.5	6.38	1.14
Total Hardness (mg/L) (CaCO3)	167.09	168	121	188	163	174	14.22	2.55
TCC MPN/100	1450.4	2400	2.0	240	210	240	1034.6	115.2
TFC MPN/100mL	1000.0	460	2.0	2400	93	2400	1006.4	112.5

Table 3. Descriptive statistics of physio- chemical parameters of water samples during post monsoon season.

Variable	Mean	Median	Min	Max	Lower Quartile	Upper Quartile	StdDev	SE
Temp	26.71	26.1	24	31	25.1	28.4	2.35	0.38
pH	6.9	7.1	6.8	8.2	6.7	7.2	0.26	0.04
Ca (ppm)	52.42	43	35.6	44.5	39	68.1	15.77	2.59
Mg(ppm)	73.76	78	37	93	60.3	85	18.12	2.98
Na(ppm)	52.98	46.9	45.1	66.4	46.2	61.9	7.852	1.29
K(ppm	4.83	4.7	4.1	5.8	4.3	5.2	0.582	0.09
Cl(ppm)	110.70	107	100.7	128	105	120	7.698	1.26
SO_4(ppm)	107.66	98.1	93	129	96.6	118	12.53	2.06
HCO_3(ppm)	112.05	96	88	176	94	119	26.36	4.33
TDS(mg/L)	579.67	590	505	709	515	609	65.37	10.74
Turbidity (NTU)	6.34	5.4	4.8	8.9	5.1	7.9	1.473	0.24
TSS(mg/L)	177.16	164	138	177	154	190	33.25	5.46
BOD_5(mg/L)	62.40	26	20	88	22	100	45.81	7.53
COD(mg/L)	88.97	90	60	139	73	100	16.43	2.70
Conductivity(mv)	1075.16	1039	1018	1257	1025	1120	66.32	10.90
NO_3(ppm)	9.24	9	8.0	12.4	8.9	9.6	0.84	0.13
PO_4(ppm)	14.43	2.4	13.1	17.3	2.1	2.6	0.45	0.07
T. Hardness (mg/L)	126.18	123	117	150	122	128	8.72	1.43

Table 4. Descriptive statistics of Heavy metals of water samples during pre and post monsoon season.

Variable	Mean	Median	Min	Max	Lower Quartile	Upper Quartile	Std Dev.	SE
Pre-monsoon								
As	0.0045	0.005	0.0001	0.01	0.0025	0.0051	0.0024	0.0031
Cd	0.1507	0.1	0.0001	0.66	0.0212	0.225	0.205	0.1651
Pb	1.403	1.275	1.0201	2.23	1.245	1.4621	0.215	0.2796
Cu	0.3845	0.361	0.0001	0.8723	0.225	0.565	0.34	0.2662
Zn	0.0404	0.011	0.0001	0.3356	0.0001	0.0575	0.0574	0.0689
Post -monsoon								
As	0.0055	0.005	0.0001	0.01	0.005	0.005	0	0.0029
Cd	0.2182	0.2	0.0001	0.66	0.06	0.36	0.3	0.1768
Pb	1.491	1.76	1.02	2.23	1.25	1.655	0.405	0.2828
Cu	0.439	0.45	0.001	0.87	0.23	0.65	0.42	0.2789
Zn	0.046	0.0115	0.0001	0.39	0.001	0.0575	0.056	0.082

Table 5. Results of PCA of physical, chemical and microbiological parameters of water samples during Pre-monsoon.

Component	Eigenvalue	Percentage variance	Cumulative percentage variance	First 4 eigenvector coefficients	Associated variables
1	8.707633	34.83053	34.83053	-0.03288	Zinc
				0.050419	Lead
				0.107738	Copper
				-0.17761	Arsenic
2	4.155762	16.62305	51.45358	-0.010967	Temperature
				-0.021443	Turbidity
				0.051174	Conductivity
				0.056427	Copper
3	2.525110	10.10044	61.55402	0.018100	TSS
				-0.056753	Hardness
				0.088933	Potassium
				0.122376	TFC

Table 6. Results of PCA of physical, chemical and microbiological parameters of water samples during Post-monsoon.

Component	Eigenvalue	Percentage variance	Cumulative percentage variance	First 4 eigenvector coefficients	Associated variables
1	9.063055	36.25222	36.25222	-0.001151	Zinc
				-0.012834	Copper
				0.026844	Nitrate
				-0.056476	Arsenic
2	2.789164	11.15665	47.40887	-0.023626	Arsenic
				-0.046842	Zinc
				-0.069827	Calcium
				-0.072997	Temperatrure
3	2.380389	9.52156	56.93043	-0.006179	TCC
				0.058483	pH
				-0.078970	Nitrate
				-0.082643	Phosphate

Total Suspended Solids (TSS) value varied from(166 to 220mg/l) and (138-177 mg/L)in pre-monsoon and post-monsoon, respectively. High TSS concentration in water samples particularly in post-monsoon period due to heavy silt load carrying along with the rain water.

Biochemical Oxygen Demand value lies between (60-110mg/L) in pre-monsoon and (20-88mg/L)in post-monsoon. High BOD_5value in pre-monsoon indicated biological activity at elevated temperature.High BOD_5 level is an indication of organic pollution which could mainly be due to high suspended solids of biological origin. Suspended solids may include a wide variety of materials, such as silt, decaying plant and animal matter that can also increase the turbidity of water (Premlata, 2009).

Chemical Oxygen Demand (COD) is key indicator of the environmental health of surface water. COD range in pre-monsoon wasfound to be 65-96 mg/L and in post- monsoon it was observed between 50-100mg/L. In the present case, there is no apparent and significant source of industrial waste at the vicinity of sample collection sites. However, untreated domestic wastewater from the nearby settlement finds its way to these sites.

Cations such as Na^{+1}, K^{+1},Ca^{+2} and Mg^{+2} are important for various metabolic processes in the body and their presence in water is necessary in a suitable concentration. However, higher concentration these cations may cause serious health problems in humans. Calcium and Magnesium are vital to human health. Inadequate intake of either nutrient can impair health. The concentration of calcium in water samples ranged between (69.9-91.4mg/L) in pre-monsoon and in post-monsoon it ranged from 35.6 to 44.4mg/L. On the other hand, magnesium content in water samples was observed between (80-103mg/L) and (37-93 mg/L) in pre and post -monsoon.

In pre-monsoon, sodium contents lies between (44.2-69.3mg/L) and (45.1- 66.9 mg/L) in post-monsoon. Similarly, amount of Potassium in pre-monsoon were 4.8 to 7.9mg/L and in post-monsoon it was recorded between 4.1 to 5.8mg/L) in both season respectively. Both surface and groundwater water normally contains low concentration of Potassium. Neither WHO nor any other organization has laid down any limits for potassium content in drinking water (Srivastava, 2003).

Nitrate in water could be due to anthropogenic sources like domestic sewage, agricultural runoff and fertilizer containing nitrogenous compounds. Nitrate concentration in water samples ranged from 8.0-13.0mg/L in both seasons which is within recommended safe permissible limit of 50 mg/L set by WHO (2005). The higher inflow of water and consequent land drainage cause high concentration of nitrate was observed in post monsoon water.

The main environmental impact associated with phosphate pollution is Eutrophication. Phosphate concentration fluctuates from 2.1-17.3 mg/L which is within permissible limit of 400mg/L set by WHO (2006). High concentration of phosphate observed during post-monsoon season could be result of agricultural runoff.

Chloride content of the water samples varied from 93-161mg/L in both seasons respectively which is within the permissible limit 250-500 mg/L as per WHO guidelines (2006). High concentration of chloride was observed in pre-monsoon which could be due to evaporation and anthropogenic influences. Our resulted is supported by Kaushik *et al.* (1991).

Mean Sulphate concentration ranged from 93-161 mg/L in pre-monsoon and post-monsoon season respectively. High concentration of SO_4^{2-} could cause a cathartic action on human beings and can also cause respiratory problems. Slightly higher sulphate concentration was noted in post monsoon season that could be contributed by anthropogenic sources.

This majorsource of water pollution in Pakistan and ultimately is a potential source of outbreak of waterborne diseases is untreated waste water (Shar *et al.* 2008a). It has been reported that the faecal coliforms up to 10^6cfu/100 mL are commonly found in India, Bangladesh, Indonesia and Pakistan (Meyberck *et al.* (1985). The people have no choice except to consume the contaminated water, therefore, water borne diseases such as gastroenteritis, diarrhea and vomiting are common among the population (Kistemann *et al.* (2001). Bacteriological analyses results revealed that most of water samples collected during both seasons were contaminated with fecal origin. Post-monsoon analysis showed an increase in bacteriological contamination which reveals that there is an increase in contamination due to organisms of public health importance after rain.This could perhaps be due to the runoff from the surroundings providing favorable conditions for the organisms to sustain and multiply. Since the number of faecal coliforms and faeal streptococci discharged by human beings and animals are significantly different, therefore it is suggested that the ratio of faecal coliforms (FC) to faecal streptococci (FS) count in a given sample can be used to detect whether they are derived from human or from animal wastes. According to WHO (1993), there is no fecal coliforms present in water samples. Bacteriological analysis of water samples are in agreementwith studies that water resources arefaecally contaminatedand may be resulted in outbreak of water borne diseases (Shar *et al*. 2008a).

The water sources usually contain low concentration of heavy metals as they dissolved these substances while moving downwards as hydrological cycle. The heavy metals are essential for metabolic activities in the body but their over exposure can lead to adverse effects on living organism including humans (Ullah *et al.* 2009).

Arsenic (As) a potentially toxic element can exist in organic and inorganic form. Arsenic in drinking water can impact human, exposure to lower levels can cause nausea and vomiting, decreased production of red and white blood cells while ingesting high levels of inorganic arsenic can cause cancer. The concentration of Arsenic (As) ranged between 0.0045 to 0.0055mgL^{-1} in both seasons respectively. These values are much lower than the tolerance limit of 10μgL^{-1}WHO (2011) for drinking water.Our finding is not in agreement with Arain et al. (2009).

Cadmium (Cd) is an element of great concern from a toxicity point of view. The safe standard for Cd concentration in drinking water set by WHO is 0.003 mg/L^{-1}.The concentration of Cd in water ranged between 0.15-0.22mg/L during study period.In both season the Cd concentrations are above the safe limit set by WHO (2011). Cadmium is a toxic metal causing both acute and chronic toxicity in animal and humans. Over exposure to high concentration of Cd may cause gastrointestinal disorder like diarrhea, vomiting and kidney damage Norberg (2004) and Barbier *et al.* (2005).

Zinc (Zn) is very essential for human health but over exposure can lead to adverse health consequences. Forwater WHO (2011) set the maximum acceptance concentration of 3mg/L. The Zn concentration of water ranged between 0.040 to 0.046mgL^{-1} is found well below the WHO limit in both seasons, respectively. The main source of Zn in water could be use of fertilizers and pesticides in the agriculture farms.

Lead (Pb) in trace amounts occur naturally in soil and water Raviraja *et al.* (2008). Thepermissible limit for lead in water is 0.001mg/L (WHO, 2011). Even at low concentration it may cause developmental delay, miscarriages and low birth weight (Bellinger, 2005), chronic exposure could adversely affects major organs and body systems i.e immunological, digestive as well as skeleton and kidneys (Gidlow, 2004). In the present study, the concentration of Pb ranged between1.40-1.49mgL^{-1} during pre-monsoon and post-monsoon season which is above acceptance limit. The higher concentration during post-monsoon season could be result of high flux of organic waste from agricultural runoff. The concentrations of Pb observed are in conformity with the results reported by Kannel *et al.* (2007) andFarooq *et al.* (2012).

Copper (Cu) is an essential metal for all living organisms, plays an important role in many enzymatic reactions. The high concentration of copper in water could cause epigastric burning, vomiting and diarrhea (Carson, 1987). Copper content present in the samples ranges from 0.001- 0.87mg/L are within the permissible limit set by WHO (2011). The seasonal variation in copper content is not significant; however a trend has been recorded with maximum concentration observed in pre-monsoon season.

The results of principal component analysis (PCA) for pre-monsoon period is given in Table 5. The first, second and third components explained 34.83, 16.82 and 10.10 percent of the total variance presnt in the data matrix. Together the first three components explained 61.55 percent of the total variability. The first component is basically a linear combination of zinc, lead, copper and arsenic. The second is fundamentally a function of temperature, turbidity, conductivity and copper, while the third component mainly depends upon TSS, hardness, potassium and TFC.

The results of principal component analysis (PCA) for post-monsoon are given in Table 6. The first, second and third components of PCA explained 36.25, 11.15, and 9.52 percent of the total. Together the first three components contributed 56.93 percent of the total variance in the data set. Therefore, these components (or factors) explain a high percentage of the total variability in the data set. The first component was largely a function of zinc, copper, nitrate and arsenic. The second component is attributable to arsenic, zinc, calcium and temperature while the third component is chiefly regulated by TCC, pH, nitrate and phosphate (Table 6). The dendrogram derived from agglomerative cluster analysis by Ward's method for pre-monsoon (Fig. 2) and post-monsoon (Fig. 3) show basically two large groups, each of which include basically the same sites for pre- and post-monsoon periods. The group on the left side for both represents relatively cleaner water compared to group 2.

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