TEMPORAL VARIATION IN GROUND WATER QUALITY DUE TO URBANIZATION. CASE STUDY: DISTRICT PESHAWAR, PAKISTAN

Mahmood Alam Khan[1], Muhammad Yaseen[1], Mujahid Khan*[2], Amjad Khan[1]

ABSTRACT

Groundwater is a significant source of water for both domestic and agricultural use. The main objective of this study was to identify temporal variations in groundwater quality of Peshawar by developing GIS based physio-chemical parameters contour maps, comparative graphs and analyse results in light of Pakistan Standard Quality Control Authority (PSQCA). In 2005, same study for district Peshawar was carried out jointly by PCSIR Peshawar and Kyungpook National University. In order to assess the effects of urbanization on ground water quality in district Peshawar, another study was undertaken in 2014-15 by collecting samples from the same locations. Standard procedures were adopted to determine the selected parameters and results of both the studies were compared. Comparative analysis of both the studies showed that some of the chemical parameters values gained an increase while other got decreased. Results also showed that electrical conductivity (EC), Cl-, SO4-2, NO3-1 were increased by 119.11%, 29.98%, 469.60%, and 59.47% respectively, while total dissolved solids (TDS), turbidity, total alkalinity, total hardness, calcium (Ca++), HCO3-1 and Magnesium (Mg++) were decreased by 6%, 10.51%, 37.39% and 11.52%, 22.21%, 37.56% and 21.19% respectively. Results revealed that changes in water quality have occurred due to over population of Peshawar and remedial measures are needed in future.

KEYWORDS: *Groundwater, Water quality, Urbanization, Contour Maps, GIS, Chemical, Physical*

INTRODUCTION

Rapid population increase in coupled with industrialization and lack of wisdom to live in harmony with nature resulted in water pollution. Developing countries are facing serious groundwater contamination problem due to agricultural, domestic, and industrial activity (Forstner *et al.,* 1981).

Due to urbanization the land surface topography is changed affecting shallow groundwater temperatures, and water table These all affect the shallow groundwater systems (Sharp, 2010).

Environmental changes are mainly caused by expanding cities due to its own population as well as migration from nearby villages. According to studies the urban population increased by 10 times as compared to world population which has doubled. In Asia, the urban population growth is much higher as compared to rest of the world. Urban population was 15 % of the total population in 1900 but now it is almost 50 % of the total population. Almost 400 cities in Asia have population more than one million (WWAP, 2006).

Ground water is affected by urbanization both quantitatively and qualitatively. This affect is because of variation in aquifer recharge as well as abstraction to the underground flow. These abstraction regimes may be cyclic and affecting the groundwater quality (Morris *et al.,* 2003). In search of good quality life, people are shifting from rural to urban areas. This mass movement is called urbanization. Due to this population growth, the cities are experiencing a number of problems and pressure is building up on the groundwater reservoirs. Besides other associated problems of urbanization, groundwater is getting depleted and clean waters are becoming polluted. In a study it was found that the principal products of urbanization are chlorides and sulphates found. From experimental results it was found that the groundwater contained ammonium, faecal coli-form and faecal streptococci bacteria which is caused by the infiltration of industrial polluted water and leakage from sewer lines (Eisena & Anderson, 1979).

Although groundwater is the best sources of water but it gets polluted due to characteristics of the media through which the water passes to become part of ground water. These contaminations are caused by heavy metals discharged by industries, traffic, municipal wastes, and

1 Department of Agricultural Engineering, UET, Peshawar-Pakistan
2 Department of Civil Engineering, UET, Peshawar-Pakistan

fertilizers used for agriculture (Biney, 1991).

Water availability per capita in Pakistan is reduced to 1200 m^3 which was 5000 in near past. Impact on quality of water can be seen from the fact that 30% to 40% of all reported diseases are water borne diseases. Moreover, it is being reported that main cause of deaths in infants and children up to 10 years and mortality rate of 136 per 1,000 live births is due to diarrhoea. It is also reported that in Khyber Pakhtunkhwa, every fifth citizen who is suffering from illness is due to polluted water (Malik *et al.,* 2010).

Inamullah & Alam, 2014 tested Ground water quality for physical, chemical, bacteriological and heavy metals. The samples were collected both from tube wells as well as consumer end. The results showed that 96.87% of the samples for chemical and physical parameters were within permissible limits, however out of samples collected from consumer ends, 84.35% were found contaminated for coliform bacteria. Out of the total samples collected from tube wells, 31.2% showed suspicious results.

A study was conducted at Narangi and surrounding areas in Sawabi to investigate the groundwater quality for physio-chemical and toxic metal concentration (Tariq *et al.,* 2015). Samples were collected from different sources like tube wells, dug wells and hand pumps. Study reveals that all the other parameters were within permissible limits except lead (Pb) and Nitrate (NO3). It was concluded that due to these contaminations, the water of the study area is not suitable for drinking.

Study was conducted in Bannu city to investigate the ground and surface water quality for fecal contamination (Khan *et al.,* 2013). Total 100 numbers of samples were collected from tube well, storage tank and consumer end. Membrane filtration technique was used to find this contamination. Results revealed that ground water is free of bacteriological commination.

Chemical quality of drinking water in specific parts of district Peshawar, Khyber-Pakhtunkhwa was assessed (Iftikhar *et al.,* 2016). They found Quality of water not in accordance to the WHO standards. They suggested to regularly monitor the drinking water resources as these can impose significant health risks.

A similar study has been conducted to analyse drinking water of Islampur area, Swat in Pakistan for phydio-chemical parameters (Hussain *et al.,* 2014). This study concluded that the water quality in the study area is unsafe for drinking purposes.

Adnan and Iqbal 2014 Ground water quality in district Peshawar, Pakistan was spatially analysed (Adnan & Iqbal, 2014). Statistical and interpolation techniques were used to spatially map the water quality parameters over the district. All the analysed parameters show greater concentration in the main city and in the North and South East part of the city. Based on the results it was suggested to install water treatment plants at various points in the district to provide safe drinking water to the inhabitants.

In 2005, the total Pakistani population in district Peshawar was 2,490,657 where 611,501 Afghanis were also living (APMSSN, 2006). According to 1998 census, Peshawar has population of 2,026,851 which has increased to 3, 405, 414 in 2016 at the growth rate of 3.29%. (Bureau of Statistics KP, 2017). Within the span of this ten years period, the increase in population people should have contributed a lot to the groundwater quality in Peshawar. The main objective of this study was to identify temporal variations in groundwater quality by developing GIS based physico-chemical parameters contour maps, comparative graphs and analyse results in light of Pakistan Standard Quality Control Authority (PSQCA).

STUDY AREA

Peshawar, capital city of Khyber Pakhtunkhwa (Pakistan) having coordinates of 34° 0' 28" N and 71° 34' 24" E as shown in Figure 1 below was taken as study area. It has semi-arid climate, suffering very hot summers and cold winters. The mean maximum and minimum temperature in study area are 40°C (104°F) and 25°C (77°F) respectively. While mean minimum and maximum temperature in winter are 4°C (39°F), and 18.30°C respectively. The localities selected for this study and its surroundings are presented in Table 1 below. Peshawar district consists of a large variety of groundwater. Water properties of one location are different from another location, source, depth and surroundings. The main objectives of this study were to identify temporal variations in groundwater quality of Peshawar, developing GIS based physio-chemical parameters contour maps and excel plots and analyse results in light of PSQCA (Pakistan) water quality standards shown in Table 2.

MATERIALS AND METHODS

Water samples were collected from the same 30 locations as were collected in the previous study carried out

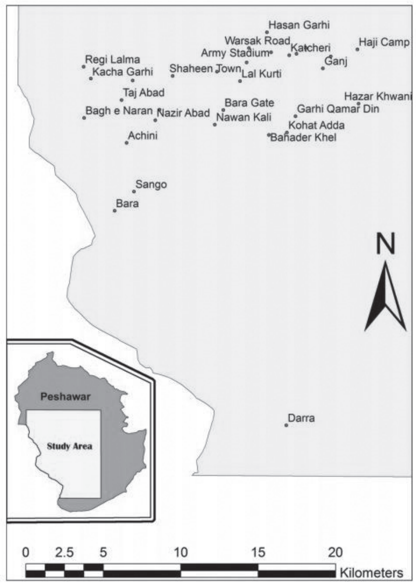

Fig. 1: Location map of the study area.

Table 1: Name, Locations, co-ordinates, state of the surroundings and source for samples collected in Current study

Sample No.	Name	Lat (oN)	Long (oE)	State of surroundings	Source
PR-01	Achini	33.9634	71.4682	Village	TW
PR-02	Army (KSK) Stadium	34.016	71.552	Park	TW
PR-03	Bagh e Naran	33.9779	71.4436	Park	TB
PR-04	Bahadar Khel	33.968	71.5508	Moderately populated	TB
PR-05	Bara	33.9241	71.4612	Moderately populated	TW
PR-06	Bara Gate	33.9824	71.5243	Populated area	TW
PR-07	Board Colony	33.9996	71.4717	Populated area	TB
PR-08	Darra	33.7996	71.5609	Village	TW
PR-09	Defence Colony	34.0101	71.5379	Populated area	TB
PR-10	Ganj Bazar	34.0066	71.5822	Populated area	TB
PR-11	GhariQamar Din	33.9789	71.5663	Populated area	TB
PR-12	Haji Camp	34.0177	71.6022	General Bus Stand	TB
PR-13	Hassan Garhi	34.0276	71.5497	Moderately populated	TW
PR-14	Hazar Khwani	33.9862	71.6028	Moderately populated	TW
PR-15	KachaGarhi	34.0008	71.4475	Village	TW
PR-16	Katcheri	34.0143	71.5626	Judicial Complex	TW
PR-17	Kohat Adda	33.9694	71.5613	Bus Stand	TW
PR-18	Lal Kurti	33.9993	71.5341	Market	TW

PR-19	Nawan Kali	33.974	71.5194	Populated area	TB
PR-20	Nazirabad	33.9766	71.4849	Moderately Populated	TW
PR-21	Nishtarabad	34.0136	71.5867	Populated Area	TW
PR-22	Radio Pakistan	34.0152	71.5668	Populated area	TW
PR-23	Regi Lalma	34.0076	71.4432	Moderately populated	TW
PR-24	Sango	33.9351	71.4725	Moderately populated	TB
PR-25	Shaheen Town	34.0023	71.4949	Populated area	TB
PR-26	Shaheen Camp	34.0048	71.5207	Cantonment Area	TW
PR-27	Shahi Bagh	34.0183	71.5723	Fun-Land Park	TB
PR-28	SufaidDheri	33.9826	71.4874	Populated area	TB
PR-29	Taj Abad	33.9883	71.4652	Village	TB
PR-30	Warsak Road	34.0184	71.5392	Petrol Pump Station	TW

Table 2: Water Quality Standards (PSQCA) (APHA, 2012)

Parameter/Characteristics	Unit	Permissible Limit
Taste	-	Tasteless
Odour	-	Odourless
Colour	-	NGVS
Temperature	-	Unobjectionable
Dissolved Oxygen	-	NGVS
Electrical Conductivity	µS/cm	NGVS
Turbidity	NTU	5
pH	-	6.5 – 8.5
Total Dissolved Solids	mg/L	1000
Total Hardness	-	<500
Calcium	-	NGVS
Magnesium	-	-
Carbonates	-	-
Total Alkalinity	mg/L as CaCO3	-
Bi-carbonates	mg/L	--
Chlorides	-	250
Sulphates	-	NGVS
Nitrates as Nitrogen	mg/L as NO3-	10

PSQCA: Pakistan Standards and Quality Control Authority

NGVS: No guideline values set

in (Khan *et al.,* 2005). These samples were then taken to the laboratory for physical and chemical analysis. All the tests were carried out using standard procedures (Long & Saleem, 1974). The quality of water is tested through physio-chemical parameters A total of 14 physio-chemical parameters as shown in Table 2 were investigated through experiments. The results obtained were then tabulated and compared with PSQCA standards. The results were also compared using excel and GIS plots.

RESULTS AND DISCUSSIONS

Results obtained from the current study are tabulated and compared with the results obtained from similar study in 2005 and is tabulated in table 3 and 4 below. The table not only show numerical comparison but also show the variation in Standard deviation and mean of data.

Statistics in (Khan *et al.*, 2005) and 2014-2015

Results of physical and chemical parameters of groundwater quality are shown in Table 3 and 4.

Table 3: Physical and Chemical Parameters of Ground Water Quality in (Khan et al., 2005) (Italic) and 2014-15

S.No	Temp (oC)	DO (mg/L)	pH	pH	EC (µS/cm)	EC (µS/cm)	TDS (mg/L)	TDS (mg/L)	Turbidity (NTU)	Turbidity (NTU)	TA (mg/L as aCO3)	TA (mg/L as aCO3)	TH (mg/L as aCO3)	TH (mg/L asCaCO3)
PR-01	20.2	9.6	7.1	7.74	390	720	530	361	3.1	1.5	196	102	392	248
PR-02	23.1	7.2	6.8	7.6	300	685	330	339	2.1	0.5	280	133	280	256
PR-03	22.3	7.5	6.3	6.91	295	576	410	288	1.8	1.8	111	147	310	235
PR-04	21.7	8.3	5.8	7.53	330	624	370	312	1.2	3.7	90	102	304	198
PR-05	18.7	8.1	7.05	7.46	380	709	436	356	2.9	6.3	185	75	332	210
PR-06	19.5	7.9	6.5	7.16	350	426	500	212	3	2.1	180	84	200	195
PR-07	19.3	8.5	6.6	7.37	315	670	400	327	1.5	1	130	117	218	192
PR-08	29.1	6.5	6.72	7.3	400	324	422	113	2.6	1.6	181	92	290	360
PR-09	18.8	7.4	6.5	7.51	340	837	400	419	3.6	0.2	230	133	330	219
PR-10	19.9	10.1	6.9	7.28	400	684	410	316	3.2	2.8	117	120	300	289
PR-11	22.4	7.4	6.3	7.27	395	907	420	543	1.2	6.6	80	80	280	213
PR-12	21.7	7.4	6.5	7.31	330	796	480	671	4.4	3.1	180	188	235	267
PR-13	22.5	8	5.7	7.42	280	634	440	313	4.5	3.3	240	71	335	270
PR-14	18.5	10.5	5.8	6.96	380	693	398	343	2.5	2.2	98	151	250	274
PR-15	21.4	9.5	6.7	7.4	200	425	339	312	1.3	2.8	115	98	320	312
PR-16	16.1	5.9	6.7	7.51	380	861	420	436	0.5	2.5	110	164	200	287
PR-17	22.7	7.1	7.8	7.94	290	871	338	436	2.9	1.8	125	124	220	257
PR-18	20.4	8.1	6.7	7.12	300	837	298	481	3	2	130	102	210	220
PR-19	19.9	10.3	6.56	7.14	320	755	497	378	3.2	2.2	192	107	360	195
PR-20	17.7	10.9	6.89	7.62	380	750	463	377	2.7	1.9	172	144	340	172
PR-21	23.2	7.6	7.5	7.67	295	807	500	401	3.1	0.5	180	129	280	227
PR-22	17.1	8.8	6.3	7.62	400	1042	415	522	1.5	1.3	950	133	195	275
PR-23	21.4	10.4	6.5	6.87	339	864	470	431	2.6	1.8	170	75	330	220
PR-24	17.5	7.2	6.9	7.38	340	716	416	465	2.6	6.8	176	71	320	175
PR-25	16.9	8.6	7.3	7.98	310	782	300	391	2.1	1.8	190	200	235	194
PR-26	20.3	9.4	5.6	7.21	290	859	348	430	2.9	3.7	290	78	240	205
PR-27	22.4	9.6	5.9	7.37	395	748	400	457	2.3	0.8	100	160	200	328
PR-28	19.6	8.4	7.06	7.37	300	643	445	323	3.8	0.4	210	133	318	261
PR-29	21.7	8.8	7.9	7.99	320	655	500	329	2.8	1.7	200	80	240	260
PR-30	20.9	8.2	6.6	7.02	380	1283	380	641	2.1	0.3	95	178	290	378
Mean	20.56	8.44	6.65	7.4	337.47	739.43	415.83	390.77	2.57	2.3	190.1	119.03	278.47	246.4
SD	2.55	1.26	0.57	0.29	48.01	181.77	60.97	113.16	0.93	1.73	153.62	36.42	54.72	52.06
% (±)			11.28		119.11		-6.027		-10.51		-37.39		-11.52	

Table 4: Physical and Chemical Parameters of Ground Water Quality in ((Khan et al., 2005) (Italic) and 2014-15

S.No	Ca++ (mg/L as aCO3)	Ca++ (mg/L as aCO3)	Mg++ (mg/L as aCO3)	Mg++ (mg/L as aCO3)	Cl- (mg/L as Cl-)	Cl- (mg/L as Cl-)	Bicar-bonate (mg/L as aCO3-1)	Bicar-bonate (mg/L as aCO3)	Car-bonate (mg/L as aCO3)	Car-bonate (mg/L as aCO3)	Sul-phate (mg/L as SO4-2)	Sul-phate (mg/L as SO4-2)	Ni-trate (mg/L as NO3-1)	Ni-trate (mg/L as NO3-1)
PR-01	152	115	240	133	85	31.99	196	102	0	0	52	195	7.1	6.1
PR-02	180	134	138	122	48	32.99	280	133	0	0	35	190	5.4	7.9
PR-03	135	98	209	137	30	41.99	111	147	0	0	39	190	5.5	8.5
PR-04	105	94	180	104	20	38.99	90	102	0	0	30	205	3.1	8.4
PR-05	118	112	214	98	26	38.99	185	75	0	0	34	175	6.9	7.4
PR-06	110	86	210	109	30	21.99	180	84	0	0	36	225	7.2	9.4
PR-07	120	82	190	110	35	13.99	130	115	0	2	36	158	5.5	6.7
PR-08	110	192	180	168	22	58	181	92	0	0	36	53	6.8	3.7
PR-09	200	114	125	105	40	38.99	230	133	0	0	70	220	5.5	33.4
PR-10	115	98	198	191	25	71.98	117	117	0	3	40	180	7.6	2.2
PR-11	120	67	170	146	35	98.97	80	80	0	0	25	325	3.8	5.6
PR-12	170	88	145	179	50	69.98	180	188	0	0	48	1475	4.5	2.4
PR-13	215	152	210	118	38	53.98	240	71	0	0	60	215	3.8	7.5
PR-14	140	108	120	166	50	130.13	98	150	0	1	40	220	5.5	6.4
PR-15	130	134	210	178	25	75.2	115	97	0	1	38	234	4.2	4.5
PR-16	170	125	135	162	50	49.98	110	164	0	0	31	170	3.7	5.7
PR-17	130	94	150	163	40	56.98	125	124	0	0	37	100	5.8	9.7
PR-18	135	102	135	118	35	42.99	130	102	0	0	38	230	6.1	8.1
PR-19	129	76	231	119	36	46.99	192	107	0	0	56	210	7.8	6
PR-20	124	58	216	114	42	47.99	172	144	0	0	39	185	7.3	12.3
PR-21	225	102	155	125	40	42.99	180	129	0	0	43	205	4.8	6.9
PR-22	150	198	120	77	40	72.98	950	133	0	0	45	160	6	5.8
PR-23	140	84	219	136	70	45.99	170	75	0	0	40	200	6.3	8
PR-24	126	58	194	117	32	47.99	176	71	0	0	29	200	6.8	10.1
PR-25	140	96	130	98	40	15.59	190	200	0	0	45	129	7.8	39.4
PR-26	190	106	130	99	53	59.98	290	78	0	0	40	375	4.3	9.1
PR-27	110	152	110	176	45	81.35	100	157	0	3	38	88	5.1	2.2
PR-28	130	116	200	145	40	36.99	210	133	0	0	80	230	7.4	4.9
PR-29	125	124	140	136	45	45.99	200	80	0	0	45	195	5.6	9.2
PR-30	137	165	150	213	60	81.97	95	178	0	0	35	240	3.9	15.1
Mean	142.7	111	171.8	135.4	40.9	53.16	190.1	118.7	0	0.33	42	239.23	5.7	9.09
SD	31.82	34.6	38.95	32.64	13.92	24.51	153.62	36.3	0	0.12	11.76	241.19	1.38	7.98
% (±)	-22.21	-21.19	29.98		-37.56				469.6		59.47			

These tabulated results are then followed by excel plots showing comparison of both the studies for thirty samples for all the physical and chemical parameters. These plots are shown in Figures 2 to 13. These figures are then followed by GIS interpolated contour maps for all these parameters comparing results of 2004 and current study in figures 14 to 27. Discussion on all the chemical parameters is presented below.

Colour: Generally, all the water samples of Peshawar district were visibly clean except samples taken from old Haji Camp (General Bus Stand) and Sango. The former had a very objectionable bluish colour while the later had muddy colour. Further, none of the samples were found to have any odour during the sampling or laboratory tests. Samples collected from three locations indicated flavour complications which were Katcheri (Judicial Complex) and Warsak Road having metallic taste while the one from Hazar Khwani had a strange taste as it was previously reported by PCSIR in its report.

Temperature and Dissolved oxygen: Table 3 indicates that the temperature of all water samples fall in the acceptable range with its average value of 20.56 °C. Figure 2 shows variation in temperature of all water samples. Similarly, from Table 3 it can be noted that the average value of dissolved oxygen is 8.44 mg/L. Figure 3 illustrates the dissolved oxygen concentration at sampling points of the study area.

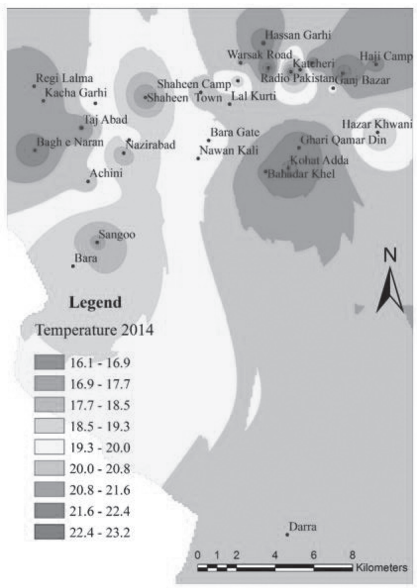

Fig. 2: Temperature (°C) Interpolation map for 2014-15.

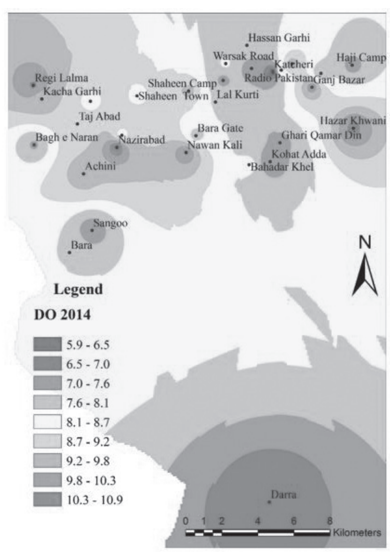

Fig. 3: DO Interpolation map for 2014-15.

H: pH is considered to be the most vulnerable part of groundwater quality. Though, the most recent results of pH for Peshawar fall in tolerable range, but the changes in its values are alarming as shown in Figure 4 as excel comparison and Figure 5 as Interpolated contour maps using GIS.

By comparing the results of current study to the previous (2004) data, it is evident that the pH value is tending to basicity. The most sensitive areas under the basicity are Taj Abad and Board Colony to the West, Sango to the South while Kohat Bus Stand to the East of the study area. Groundwater in Taj Abad and Board

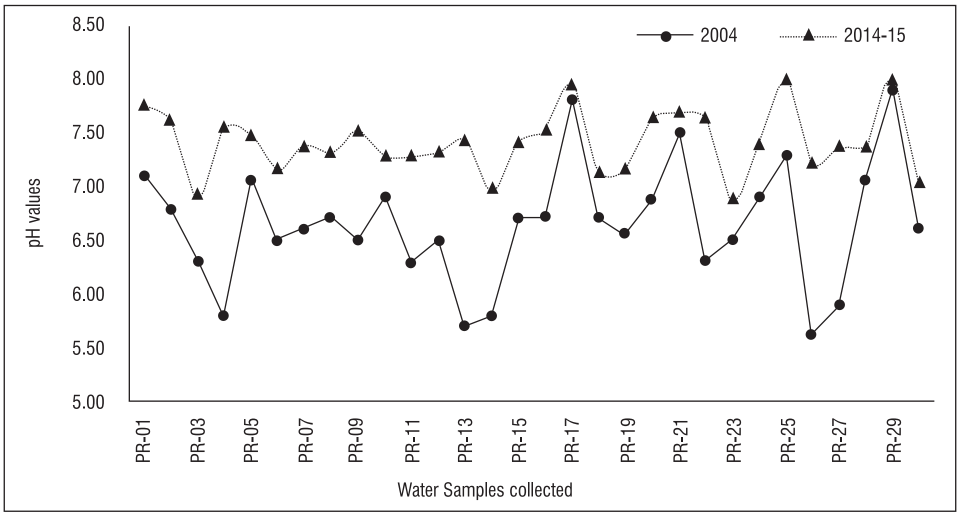

Fig. 4: Comparison of pH value for Current study with study conducted by (Khan *et al.*, 2005).

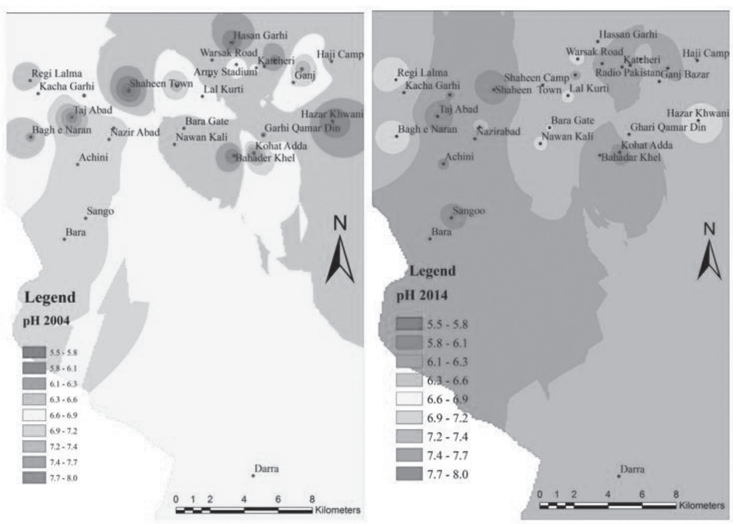

Fig. 5: pH Interpolation map for (Khan et al., 2005) (Left) and Current Study (Right).

Colony are directly affected by a drain that passes through it, since its waste waters contain municipal sewage and sullage. Seepage and deep percolation takes place in this area which raises the basicity of groundwater. Its average value has increased from 6.65 to 7.4 (11.28%) because of the uncontrolled disposals of sewage and wastes./

EC, TDS and turbidity: Results show an increase in average value of EC from 337.47µS/cm to 739.43µS/cm (119.11%). Figure 6 in excel plot and Figure 7 of GIS based interpolated contour plot shows Warsak Road to be the most sensitive area based on the present study.

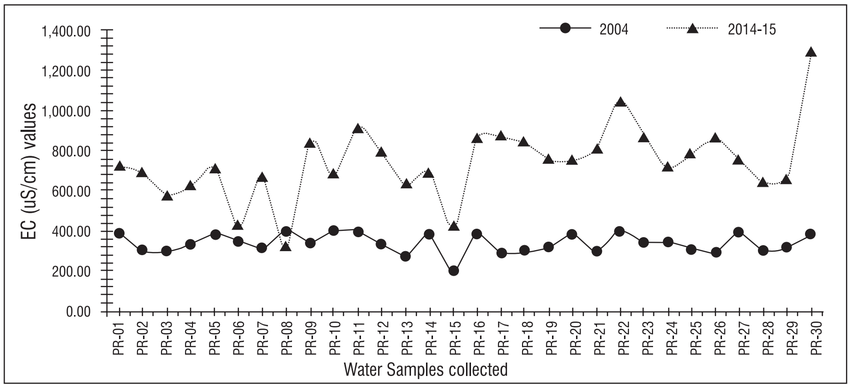

Fig. 6: Comparison of Electrical Conductivity values for Current study with study conducted by (Khan *et al.,* 2005.)

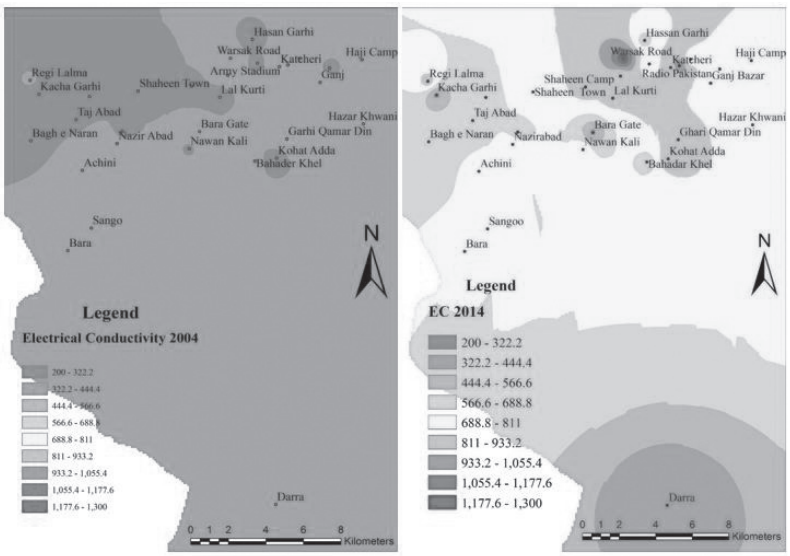

Fig. 7: Electrical Conductivity (μS/cm) Interpolation map for (Khan *et al.,* 2005) (Left) and Current Study (Right).

For TDS, its average value has decreased from 415.83 mg/L to 390.77 mg/L (6.03%). TDS concentrations at sampling points are shown in Figure 8 as excel plot comparing results of both studies while the same comparison is also shown in Figure 9 using interpolated contour maps drawn using GIS.

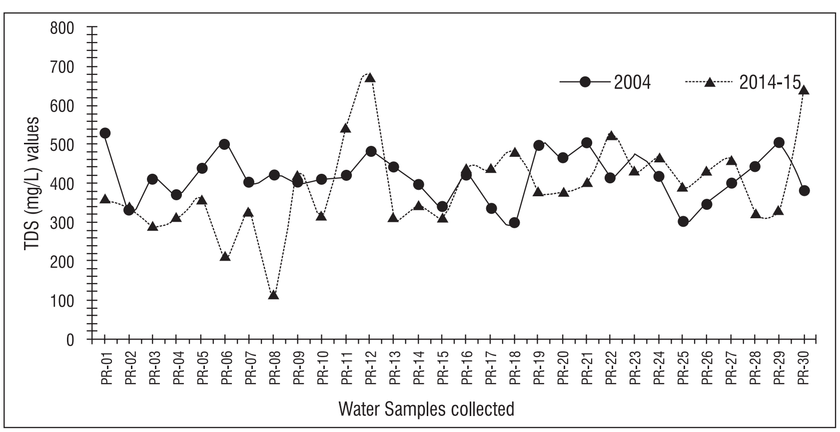

Fig. 8: Comparison of (TDS) values for Current study with study conducted by (Khan *et al.,* 2005).

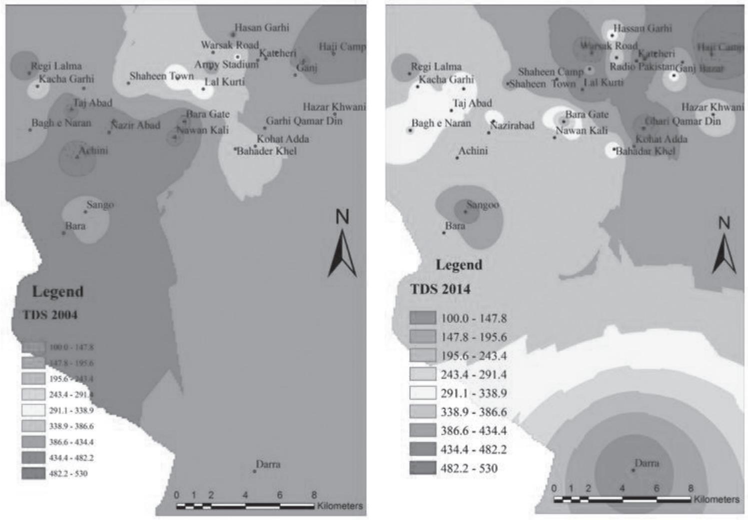

Fig. 9: Total Dissolved Solid Interpolation map for 2004 (Khan *et al.*, 2005) (Left) and Current Study (Right).

Similarly, average value of turbidity has decreased from 2.57 NTU to 2.30 NTU (10.51%). This trend in turbidity is shown in Figure 10 through excel plot and in Figure 11 using GIS-based interpolated contour plots.

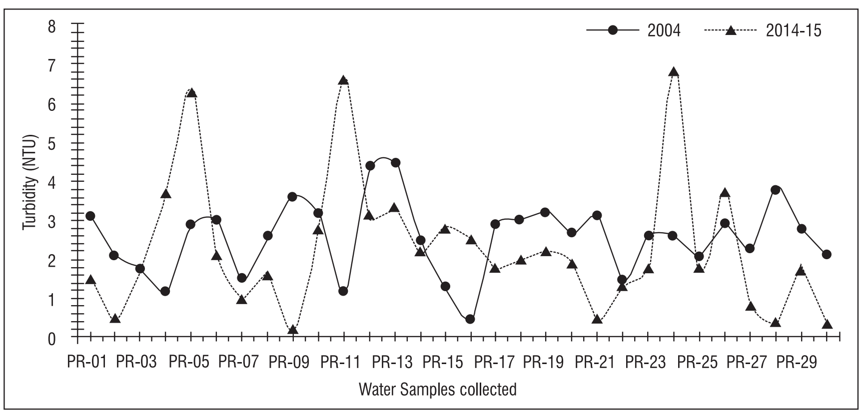

Fig. 10: Comparison of Turbidity values for Current study with study conducted by (Khan *et al.,* 2005).

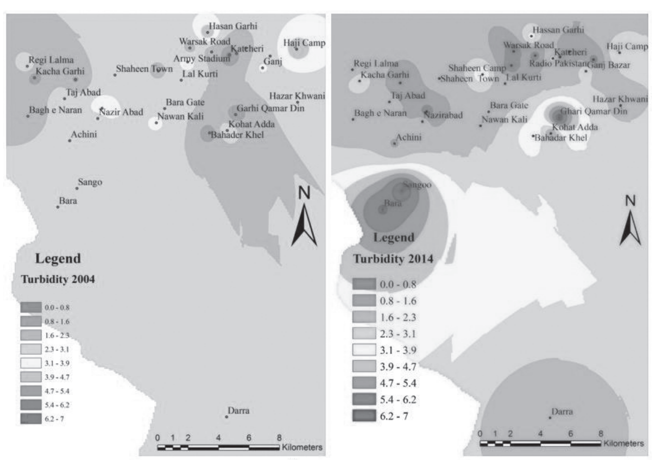

Fig. 11: Turbidity (NTU) Interpolation map for (Khan *et al.,* 2005) (Left) and Current Study (Right).

Total Alkalinity: The average value of total alkalinity has decreased from 190.1 mg/L as $CaCO_3$ to 119.03 mg/L as $CaCO_3$ (37.39%). By looking at Table 3, the mean value of total hardness exceeds that of total alkalinity which means that there is permanent hardness present in all water samples except that of Shaheen Town where total alkalinity is greater than total hardness because of the presence of bicarbonates in it. Figure 12 shows this variation comparison in total alkalinity concentration using excel plot while Figure 13 shows the same variation by drawing interpolated contour maps using GIS.

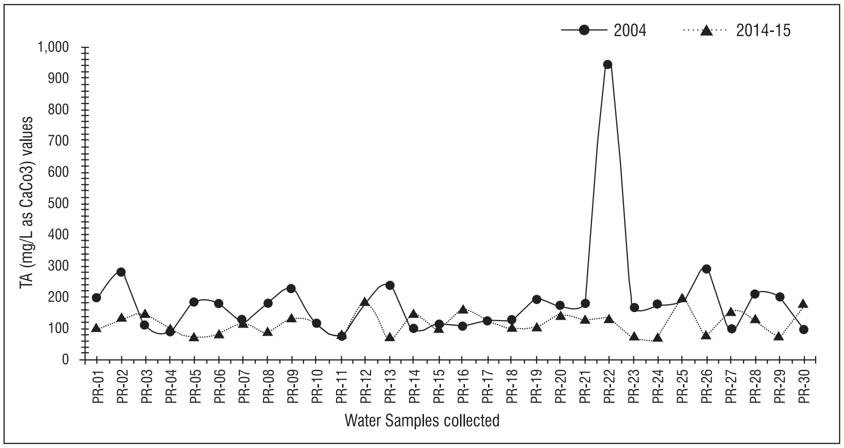

Fig.12: Comparison of Total Alkalinity as CaCO3values for Current study with study conducted by (Khan *et al.,* 2005).

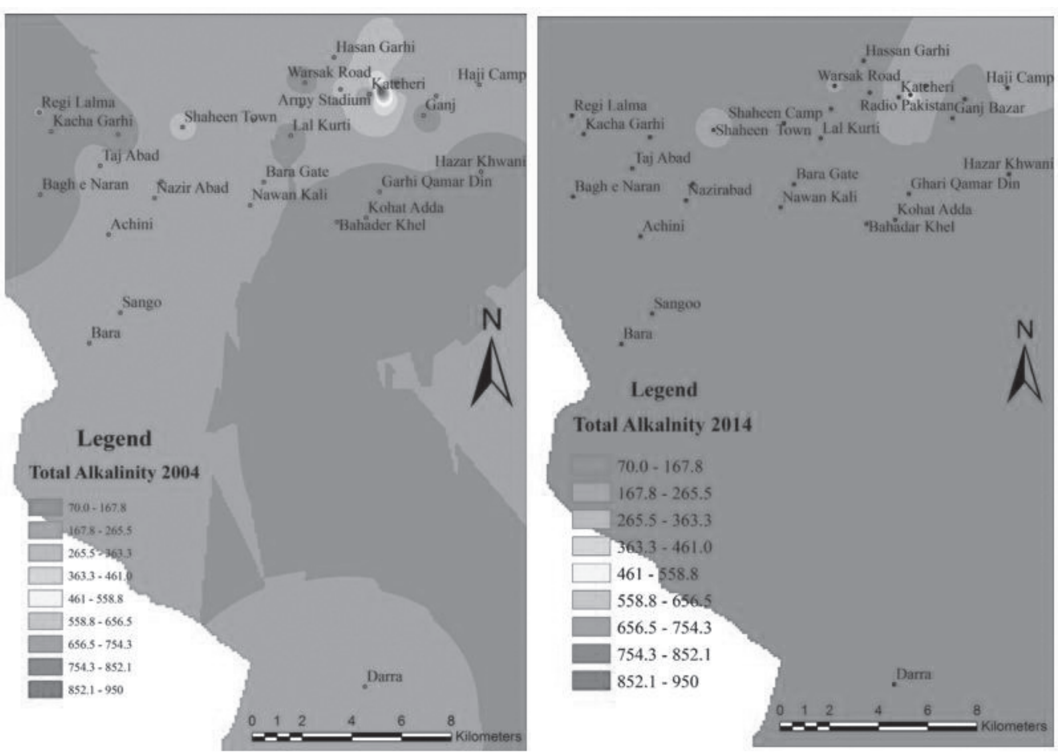

Fig. 13: Total Alkalinity Interpolation map for (Khan *et al.,* 2005) (Left) and Current Study (Right).

Total Hardness: The average value of total hardness has decreased from 278.47 mg/L as $CaCO_3$ to 246.40 mg/L as $CACO_3$ (11.52%) as depicted from Table 3. Changes in concentration of total hardness are shown in Figure 14 using excel plots and in Figure 15 using GIS based contour maps, where Warsak Road and Darra have the highest concentration of total hardness under the present study. With overall reduction in total hardness, reduction both in calcium and magnesium contents has resulted in total hardness. Results indicate that all the water samples satisfy water quality criteria.

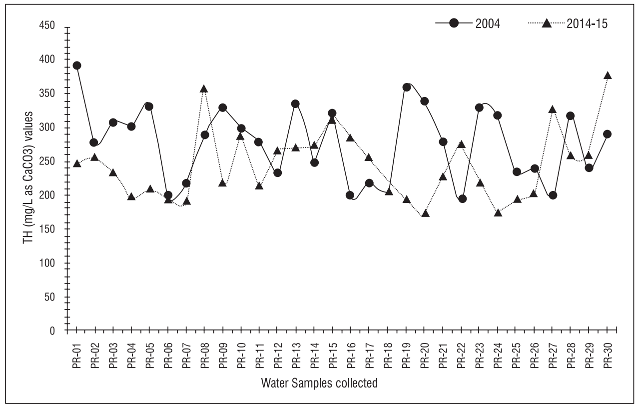

Fig. 14: Comparison of Total Hardness values for Current study with study conducted by (Khan *et al.,* 2005).

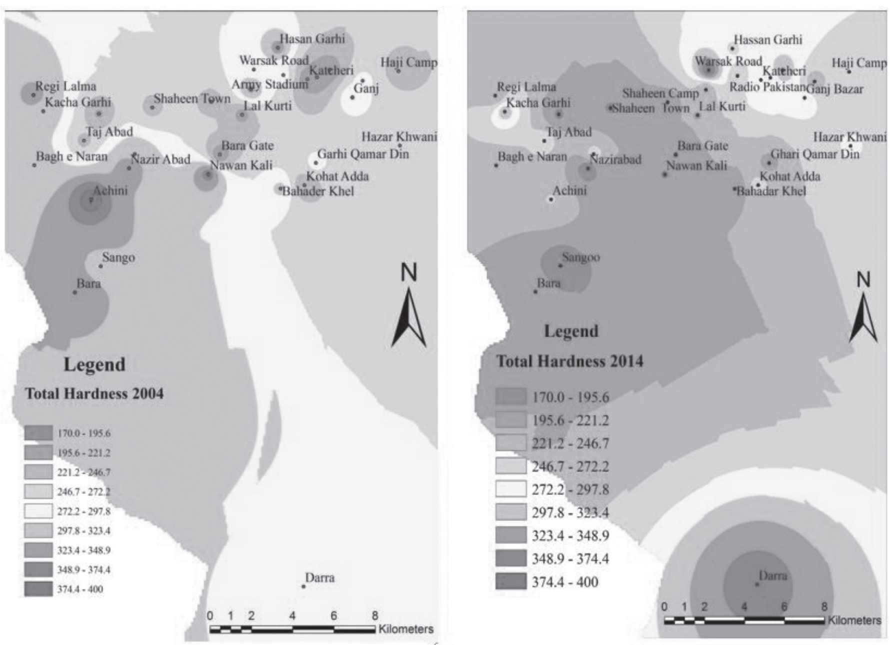

Fig. 15: Total Hardness Interpolation map for (Khan *et al.,* 2005) (Left) and Current Study (Right).

Calcium and Magnesium: Table 4 shows that the average value of calcium has decreased from 142.70 mg/L as $CaCO_3$ to 111 mg/L as $CaCO_3$ (22.21%) and magnesium from 171.80 mg/L as $CaCO_3$ to 135.40 mg/L as $CaCO_3$ (21.19%). Almost all the water samples except few did not meet the water quality criteria as set in Table 2 for magnesium. By looking at the averages, one can infer that the decrease in magnesium contents is more than that of calcium, but in fact, by observing individually, it is evident that magnesium is greater than calcium (23 samples out of 30) as compared to earlier studies where it was 18 out of 30. Among all the samples, Darra and

Warsak Road have the maximum content of calcium as shown in Figure 16 as well as in Figure 17 as GIS based contour maps. Similar variation comparison for magnesium is shown in Figure 18 and Figure 19 using excel and GIS respectively.

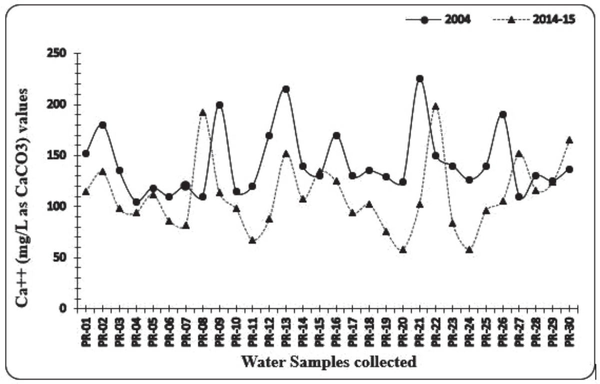

Fig. 16: Comparison of Calcium values for Current study with study conducted by (Khan *et al.,* 2005).

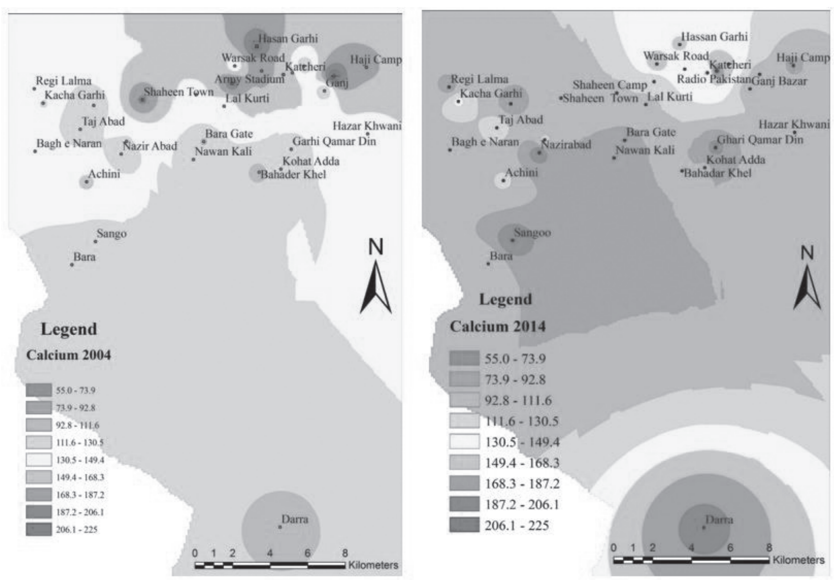

Fig. 17: Calcium as CaCO3Interpolation map for (Khan *et al.,* 2005) (Left) and Current Study (Right).

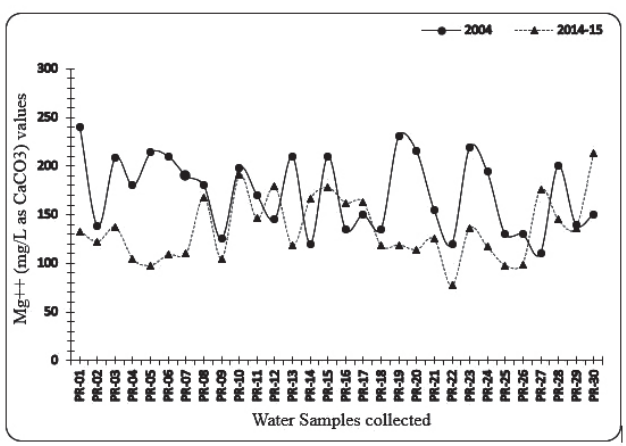

Fig. 18: Comparison of Magnesium values for Current study with study conducted for (Khan *et al.,* 2005).

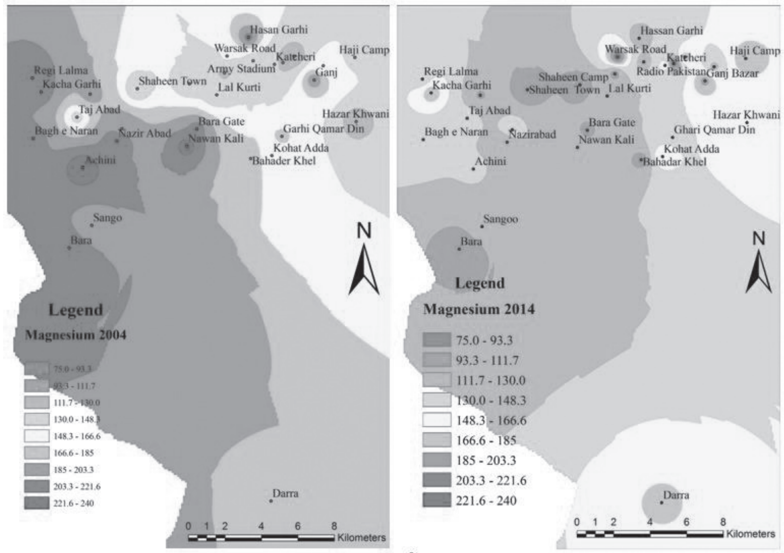

Fig. 19: Magnesium as CaCO3 Interpolation map for (Khan *et al.*, 2005) (Left) and Current Study (Right).

Chlorides and Bi-carbonates: An increase in average chloride concentration from 40.90 mg/L as Cl^- to 53.16 mg/L as Cl^- (29.98%) is shown in Table 4. By looking at Figures 20 and Figure 21, a decrease of chloride concentration in western parts of the study area can be seen while a significant increase in eastern parts like Hazar Khwani and Garhi Qamar Din can be noticed. All the water samples in the study area satisfy the PSQCA criteria as given in Table 2.

The average value of Bi-carbonates in the study area decreased from 190.1 mg/L as Ca CO3 to 118.70 mg/L as Ca CO3 (37.56%) as listed in Table 4. The bicarbonates show a difference of 71.4 mg/L as CaCO3 (slightly more than that of TA) because of the small presence of carbonates in samples of Kacheri and Radio Pakistan. The average value of bicarbonates for 2014-15 has been found to be less than that of total alkalinity because some of the locations like Kacheri and Radio Pakistan were found to have some traces of carbonates as evident from Table 4. Figures 22 and Figure 23 show variations in Bi-carbonates in 2004 and 2014-15 using Excel and GIS respectively.

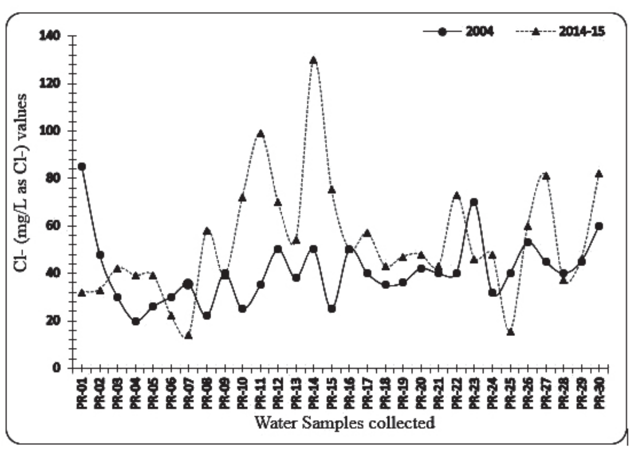

Fig. 20: Comparison of Chloride values for Current study with study conducted by (Khan *et al.*, 2005).

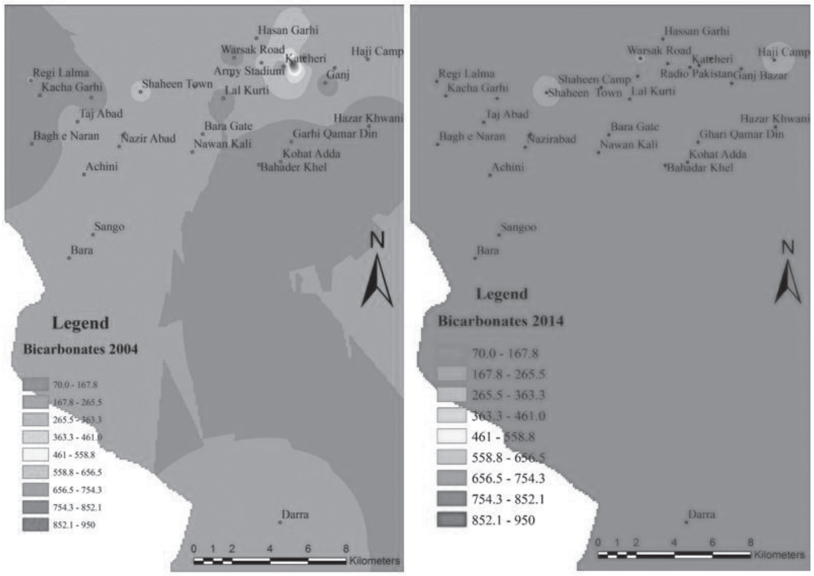

Fig. 21:Bicarbonates Interpolation map for (Khan *et al.,* 2005) (Left) and Current Study (Right).

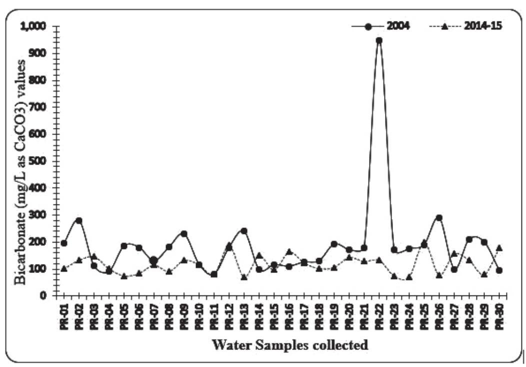

Fig. 22: Comparison of Bicarbonate values for Current study with study conducted by (Khan *et al.,* 2005).

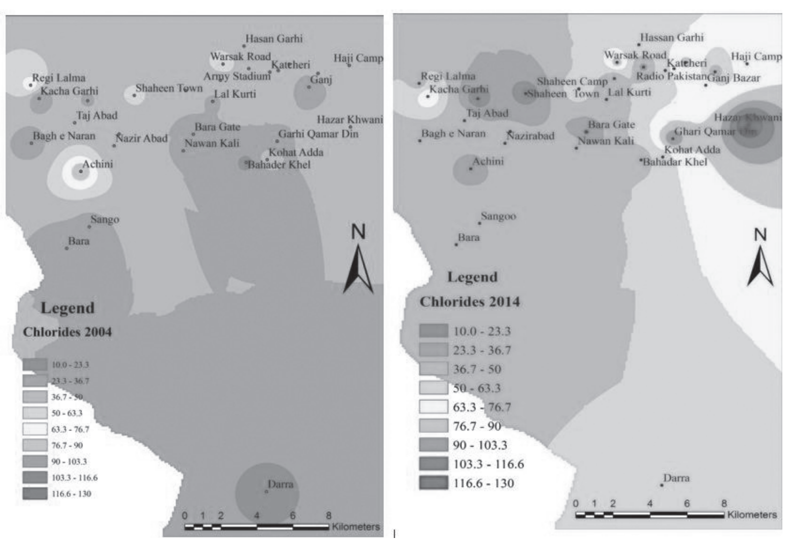

Fig. 23: Chloride Interpolation map for (Khan *et al.,* 2005) (Left) and Current Study (Right).

Sulphates and Nitrates: Similarly, there is an increase in average value of sulphate concentration from 42 mg/L as SO_4^{-2} to 239.23 mg/L as SO_4^{-2} (469.60%). Area which doesn't meet the criteria of water quality for sulphates is Haji Camp where the concentration is 1475 mg/L. Figure 24 and Figure 25 show variations in sulphates concentration of the two studies.

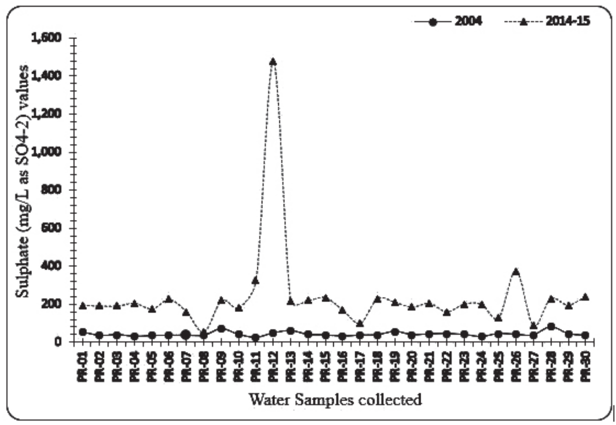

Fig. 24: Comparison of Sulphate values for Current study with study conducted by (Khan *et al.*, 2005).

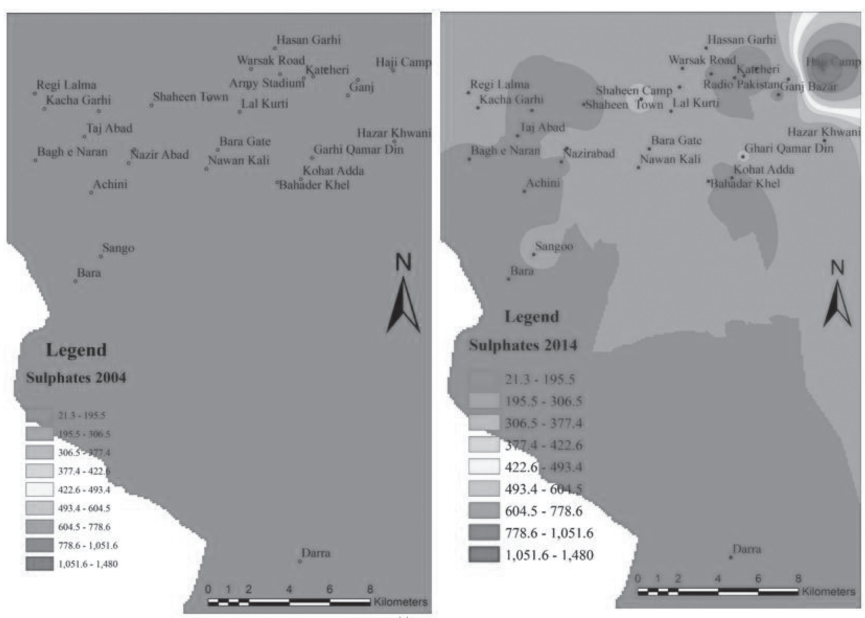

Fig. 25: Sulphates (mg/L as SO4-2) Interpolation map for (Khan *et al.*, 2005) (Left) and Current Study (Right).

From Table 4, average value of nitrates has increased from 5.70 mg/L as NO_3^{-1} to 9.09 mg/L as NO_3^{-1} (59.47%). Areas such as Defence Colony, Nazirabad, Sango, Shaheen Town and Warsak Road have increased concentration of nitrates. The worst areas are Defence Colony and Shaheen Town where Nitrates concentrations are 33.4 mg/L as $NO_3^{-1}$and 39.4 mg/L as NO_3^{-1} respectively. Based on the water quality, all the samples satisfy the criteria set by PSQCA. Variation in nitrates concentration for both the studies can be seen in Excel based Figure 26 and GIS based contour map in Figure 27. Concentration of sulphates and nitrates show an alarming increase in 2014-15 as compared to 2004. This increase is not a good sign for the area to be placed as hygienically clean.

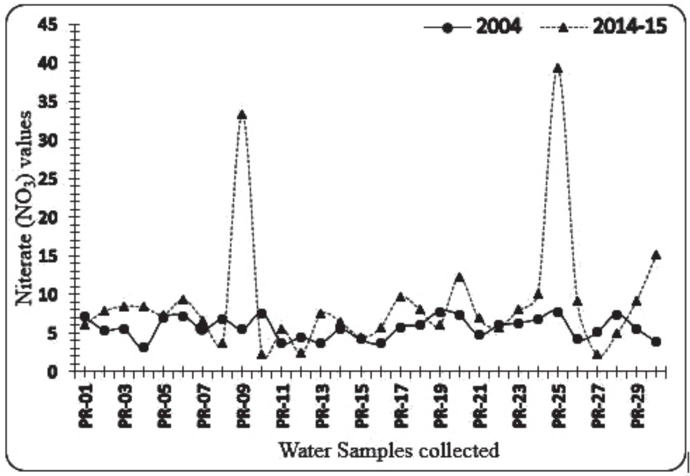

Fig. 26: Comparison of Nitrate values for Current study with study conducted by(Khan *et al.,* 2005).

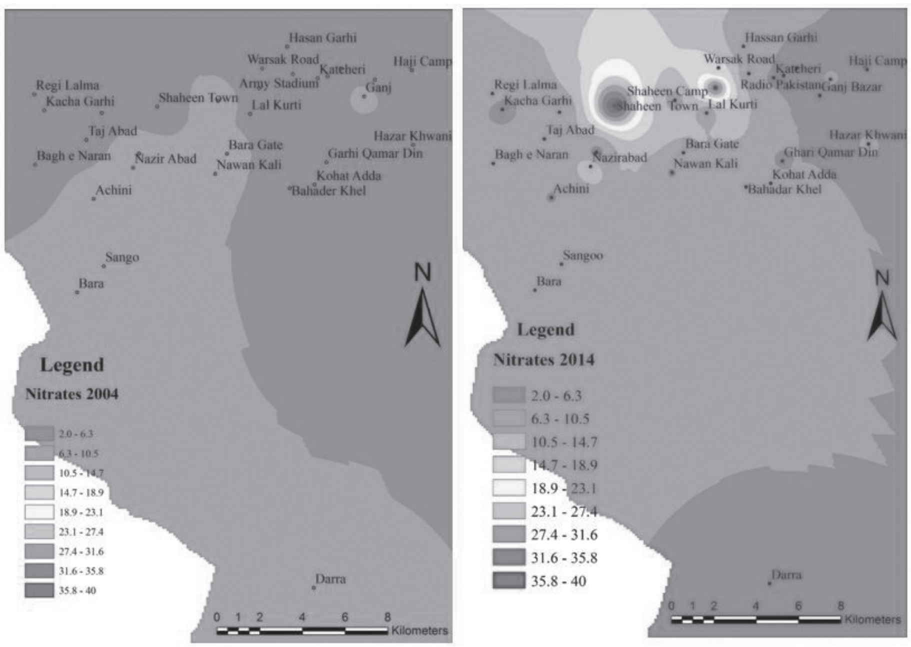

Fig. 27: Nitrates Interpolation map for (Khan *et al.,* 2005) (Left) and Current Study (Right).

CONCLUSIONS

From the recent study, it is evident that groundwater is enriched in chlorides and sulphates as compared to the previous study which supports the suggestions given by (Schicht, 1977) and (Imran *et al.,* 2016), who reported that the principal products of urbanization which alter ground water chemistry are chlorides and sulphates. High sulphate levels (1000 mg/L) have been found to have laxative effect on humans and can cause mild gastrointestinal irritation. High sulphate levels of 1475 mg/L have been found in Haji camp area which is an alarming for inhabitants of the area. PSQCA have set the maximum contamination level for nitrates in drinking water as 10 mg nitrates-N/L (APHA, 2012). When we look at the statistics under present study, some of the areas such as Defence Colony, Nazirabad, Sango, Shaheen Town and Warsak Road have exceeded this standard. The worst areas are Defence Colony and Shaheen Town where nitrates concentrations are 33.40 mg nitrates-N/L and 39.40 mg nitrates-N/L respectively.

The use of fertilizer, decayed vegetables and animal matter, domestic effluents, sewage disposal on land, industrial discharge, leachate from refuse dumps and atmospheric wash outs contribute nitrate in water. There are two major health concerns when drinking waters are used with high levels of nitrates or nitrites. The first health concern is with infants at risk for "blue baby syndrome" also called "Methemoglobinemia" which enables infants blood less oxygen carrier due to poisoning. The second health concern with nitrates and nitrites is the formation of chemical called nitrosamine in the digestive tract which is being studied for link to cancer. Pregnant women are at greater risk to this disease (APHA, 2012).

Future research of similar nature needs to be extended into other parts of Khyber-Pakhtunkhwa. Similarly, groundwater quality parameters presented in this study needs to be analysed with a period of each two to three years to see the effects and effort should be made for possible solution in time.

REFERENCES

1. *Adnan, A., & Iqbal, J., (2014), "Spatial analysis of the ground water quality in the Peshawar district, Pakistan", 12th international conference on computing and control for the water industry. Procedia Engineering, Vol. 70, pp. 14-22. doi: 10.1016/j.proeng.2014.02.003*

2. *Afghans in Peshawar: Migration, Settlements and Social Networks. (2006). Afghanistan Research and Evaluation Unit, Charahi Ansari, Shar-e-Naw Kabul, Afghanistan. p. 05.*

3. *APHA (2012), "Standard Methods for the Examination of Water and Waste Water", 22nd ed. American Public Health Association and Water Pollution Control Federation, New York, Washington, DC.*

4. *Biney, C. A., (1991), "The distribution of trace metals in the Kpong Head pond and lower Volta River, Ghana. In: Perspectives in aquatic Ecotoxicology; Shastree, N.K. Delhi, India Narendara Publishing House, pp 321-340.*

5. *Development Statistics of Khyber Pakhtunkhwa, Bureau of Statistics Khyber Pakhtunkhwa, (2017), p. 159 (Wikipedia).*

6. *Eisena, C., & Anderson, M. P., (1979), "The Effects of Urbanization on Ground-Water Quality- A case study", Global Water, Vol. 17, No. 5, pp. 456–462, 10.1111/j.1745-6584. 1979.tb03341. x.*

7. *Förstner, U., Wittmann, T. W., Prosi, F., & Van. Lierde, J., (1981), "Metal Pollution in the Aquatic Environment", XF2006212406. 10.1007/978-3-642-96511-1-8.*

8. *Hussain, R., Ali, L., Hussain, I., & Khattak, S.A., (2014), "Source identification and assessment of physico-chemical parameters and heavy metals in drinking water of Islampur area, Swat, Pakistan"' Journal of Himalayan Earth Sciences, Vol. 47, No. 1, pp. 99-106.*

9. *Iftikhar, B., Bashirullah, N., Ishtiaq, M., Khan, S.A., Siddique, S., & Ayaz, T., (2016), "Chemical quality assessment of drinking water in district Peshawar", Pakistan. Khyber Medical University Journal, Vol. 8, No. 4, pp. 171-176.*

10. *Imran, S., Anwar, K., Bukhari, L.N., & Ashraf, M., (2016), "Water Quality Status of Major Cities of Pakistan 2015-16", Pakistan Council of Research in Water Resources, Ministry of Science and Technology. p. 15*

11. *Inamullah, E., & Alam, A., (2014), "Assessment of Drinking Water Quality in Peshawar, Pakistan", Bulgarian Journal of Agricultural Science, Vol. 20, No. 3, pp. 595-600.*

12. *Khan, A. U., Iqbal, Q., Fayaz, A.K., & Ashraf, S., (2013), "Impact of Urbanization on potable water quality: A bacteriological case study of Bannu city", Science International Lahore, Vol. 25, No. 4, pp. 559-564.*

13. *Khan, A.R., Mumtaz., Kyung-Sok, M., Marwat, G.A., & Riaz, M. M, (2005), "Potable water quality characteristics of the urban areas of Peshawar (Pakistan) Part 2: Well water", Journal of chemical society Pakistan, Vol. 27, No.3, pp. 239-245.*

14. *Long, D.T., & Saleem, Z.A., (1974), "Hydro Geochemistry of Carbonate Ground Waters of an*

Urban Area". Water Resources Research, Vol. 10, No. 6, pp. 1229-1238.

15. *Malik, M. A, Azam, M., & Saboor, A. (2010), "Water Quality Status of Upper KPK and Northern Areas of Pakistan", Pakistan Council of Research in Water Resources (PCRWR), Water Resources Research Centre Peshawar, Ministry of Science and Technology. pp. 13-20.*

16. *Morris, B.L., Lawrence, A.R.L., Chilton, P.J.C., Adams, B., Calow, R.C., and Klinck, B. A., (2003), "Groundwater and its Susceptibility to Degradation: A Global Assessment of the Problem and Options for Management Early Warning and Assessment", United Nations Environment Programme, Nairobi, Kenya.*

17. *Schicht, R.J., (1977), "The Effect of Precipitation Scavenging of Airborne and Sulphate Pollutants on Surface and Groundwater Quality in Urban Areas: Final Report-part 1: Groundwater Studies", Ill. State Water Survey, Urbana: NFS-Engineering Div. Report, NSFGK-38329, p. 57*

18. *Sharp, J.M. Jr., (2010), "The Impacts of Urbanization on Groundwater Systems and Recharge", AQUA mundi (2010) - Am01008, pp. 051 – 056, DOI 10.4409/Am-004-10-0008.*

19. *Tariq, M., Khan, S., Ali, L., Anjum, S., Latif, K., Hussain, R., & Yousaf, S., (2015), "Assessment of drinking water quality in Narangi and surrounding areas of district Swabi, Pakistan", Journal of Himalayan Earth Sciences, Vol. 48, No. 1, pp.81-88.*

20. *World Water Assessment Report by UNESCO, (2006), "Water: a shared responsibility", The United Nations World Water Development Report 2. UNESCO, Paris and Berghahn Books, New York.*