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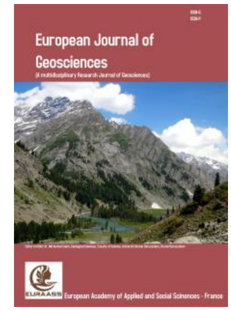

Research Article

Physico-Chemical Analysis, Classification of Ground Water, and Impact of Water Quality on the Health of People in Khushab City, Pakistan

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Abstract

A study was carried out to analyze the ground water samples from fifty sites within the urban settlements of Khushab city, Pakistan in order to understand the distribution of contaminants and its impact on public health in the studied area. All the water samples were analysed using physico-chemical parameters: pH, Electric Conductivity (EC), Total Dissolved Solids (TDS), Total Hardness (TH), Ca^+, Mg^+, Cl^- and NO_3 by using standard analytical methods. Salinity hazard was evaluated by using EC values inferred from the water samples. Water samples were classified on the basis of TDS and TH. Arc GIS software was used to plot the spatial distribution of contamination, concluded from the observed physico-chemical parameters throughout the study area. A door to door survey was also conducted to get the feedback from 100 people living in the houses, working in offices and shops to know the issues of water quality along with the level of satisfaction for the present water quality. Results showed that pH value ranging between 6.8 and 8.7, EC between 260 and 10290 µS/cm, TDS between 179 and 9410 mg/l, Ca^{+2} between 1.2 and 11.8 mg/l, Mg^{+2} between 0.3 and 39.4 mg/l, TH between 6.23 and 216.86 mg/l, Cl^- between 0.3 and 344.7 and NO_3 between 12 and 62 mg/l. Results showed certain sites indicating poor water quality through deviation from WHO standard values of certain physico-chemical parameters. This showed that ground water at particular sites within the study area was unfit for drinking purpose and its prolonged utilization could cause serious health issues. More than 62% people reported their dissatisfaction regarding water quality and 80% agreed that water quality has drastically declined. Results were also correlated with the data collected from the Tehsil Headquarter Hospital which demonstrated that residents of Khushab city were suffering from the water borne diseases like Hepatitis, Cholera, Gastro, and Kidney stone etc. Almost 40,000 patients from Khushab city and the surrounding villages who suffered from water borne diseases visited the Tehsil Headquarter Hospital in the year 2014. It has been concluded from the study that the ground water of the study area has declined and needs proper and urgent attention from the government and water must be processed through state of the art purification treatment plants, before supplying to people for drinking and domestic purposes.

Keywords:

Physico-chemical, Electric Conductivity, Total Dissolved Solids, Total Hardness, Contamination.

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1. Introduction

Life on the blue planet is hooked with the water and one of the vital source of its supply is ground water. Water quality in a particular area is function of numerous physical and chemical parameters that are very much affected by the atmospheric input, geological formations, urbanization, industrialization, and agricultural activities etc. (Bahri and Saibi, 2010, Alam, 2014). In the past importance of water quality was never highlighted as the way it is discussed on every forum in present era. One of the major reasons is the fact that population blast, industrial and agricultural revolution all have made the human beings dependent much more upon the groundwater in last few decades (Alam, 2014). As a consequence of intense exploitation of groundwater and addition of untreated human and industrial wastes to water bodies have caused the decline in water quality (Sajil Kumar et al. 2014). The present study highlights the investigation of groundwater quality through various physical and chemical parameters in urban settlements of Khushab district, Punjab, Pakistan.

Groundwater quality was investigated on the basis of various physical e.g. total dissolved solids (TDS), electrical conductivity (EC), total hardness (TH) and chemical parameters e.g. pH, Mg, Ca, NO_3^-, Cl^-. Using the level of concentration of different parameters classification of groundwater was conducted and possibility of its usage in drinking, industry and agriculture was also evaluated. Moreover, the spatial distribution of different parameters within the study area was also observed by developing ARC GIS maps. Waterborne diseases are one of the main reasons of health problems in the developing countries as a consequence of which high mortality rate is observed especially among children up to 5 years (M. Sheikh et al., 2015). Therefore, the study was conducted in such way that it also focused the impact of the water quality on people residing in the study area. A detailed survey was also conducted comprising of structured questionnaires. The survey highlighted people's opinion about the water quality issue in the study area keeping in view the work conducted by Dahunsi et al., (2014).

2. Geographical and Geological Settings of the study area

Khushab city lies between 32.300°N latitude and 72.340°E longitude having a total population of 9,05,711 (Population Census organization 2001). Khushab city is located in Punjab province of Pakistan (Figure 1) at 200 m above sea level with hot and dry climatic conditions during summer (Sultan and Ahmad, 2008). The average temperature during summer ranges between 39°C and 29°C while it ranges between 22°C and 6°C during winters. The estimated annual average rainfall within the study area is 450 mm with a variable frequency and insufficient amount. Maximum precipitation is observed during July i.e. 100 mm while November is concerned as the driest month with 5 mm precipitation (Climatic Normals Pakistan;1971-2000). Few other parameters related to hydro climatology are mentioned in Table 1.

Table1: Hydro-climatic characteristics of the Khushab city (PMDC-2014).

Parameters	Values
Annual Precipitation	450 mm
Average atmospheric temperature (ºC)	24.5ºC
Average Evapo-transpiration rate	2.65mm/day
Average Humidity	58%
Koppen-Gieger Climate Classification	BSh

Khushab city is situated near the Salt Range foothills which are composed of highly fractured and folded rocks containing fossils of Precambrian to Pliestocene age. Detailed stratigraphy of the study area is shown in the figure 2. Khushab is part of the Indus plains which is drained by Indus river and its main distributaries. Each flat zone in the Indus plain is called as Doab, meaning a land surrounded by two rivers (Thatte 2008). Five doabs are also present with in the Indus plains namely Thal Doab, Chaj Doab, Rechna Doab, Bari Doab and Bist Doab. The study area constitutes the northeastern part of Thal Doab and is fed by Jhelum River. According to the study conducted by Swarzenski (1965) unconsolidated but highly permeable alluvium deposits are residing over the study area up to a depth of more than 300 m. These alluvium deposits are composed of fine to medium sand, clay and silt. Moreover, low permeable material of discontinuous nature is also present within the Indus plain. Therefore, sand makes up almost 70% of the alluvium and serve as highly transmissive aquifers (Cheema and Bastiaanssen, 2010). The coefficient of permeability is in the range of 0.05 to 1.2 m/sec in the study area (Greenman et al., 1967). Khushab city is generally comprising of thick but unconsolidated Quaternary alluvial and aeolian deposits residing over the basement rocks of Precambrian age.Coarser concentrated sediments are present near Quaidabad and Bundiyal upto depth of more than 180 m. The flood plains of Jehlum river is underlain by thick sand deposits with small amount of gravels. The sand deposits contain thin lenses of silt and clay having limited vertical and lateral extension (Akram et al., 2014). Aquifers are recharged by the River Jhelum through its bed and flooding on flood plains. Another important source of recharging aquifer is rain water in the study area.

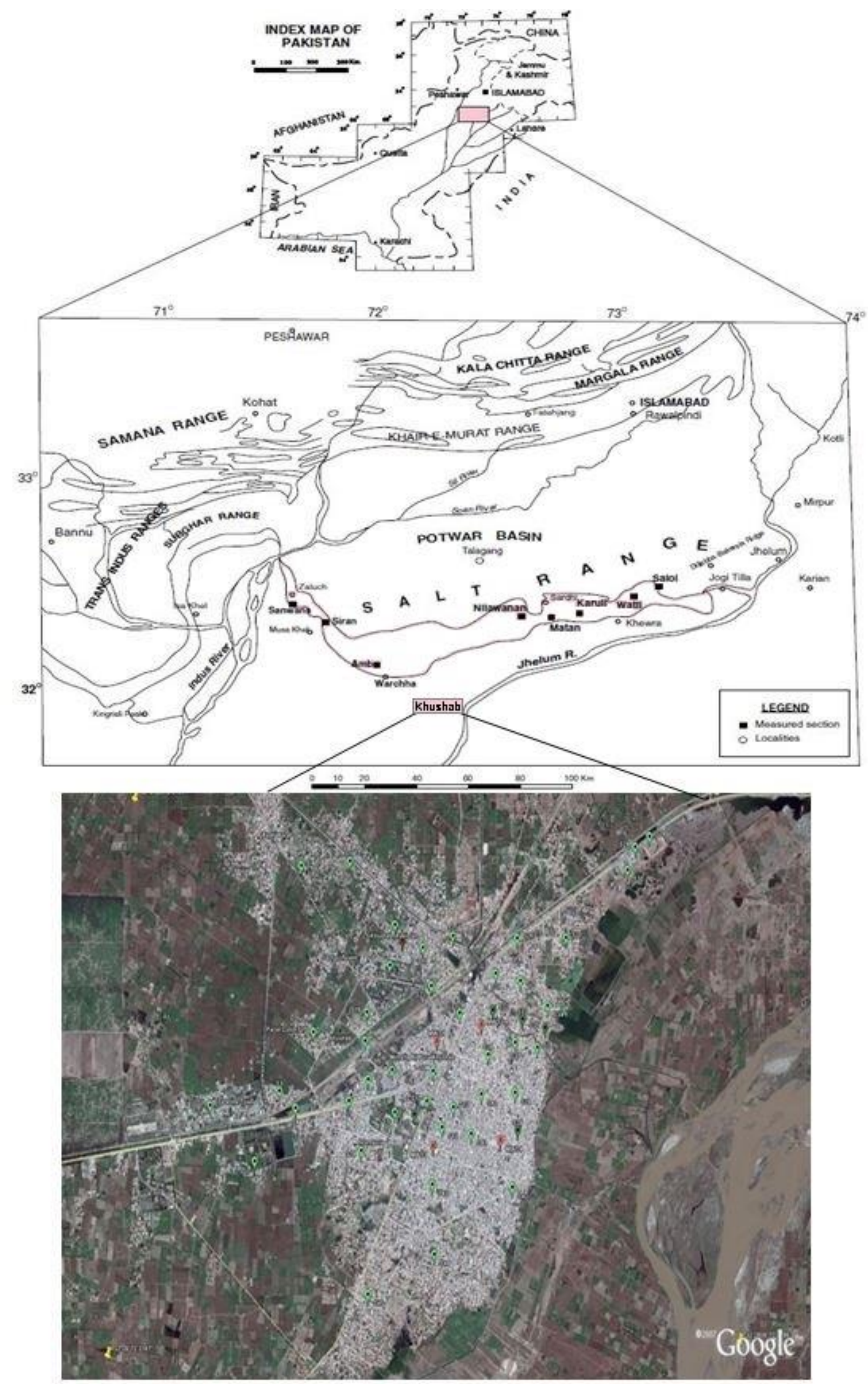

Figure 1: Geographical map of the study area and satellite image of Khushab city along with sites of data collection.

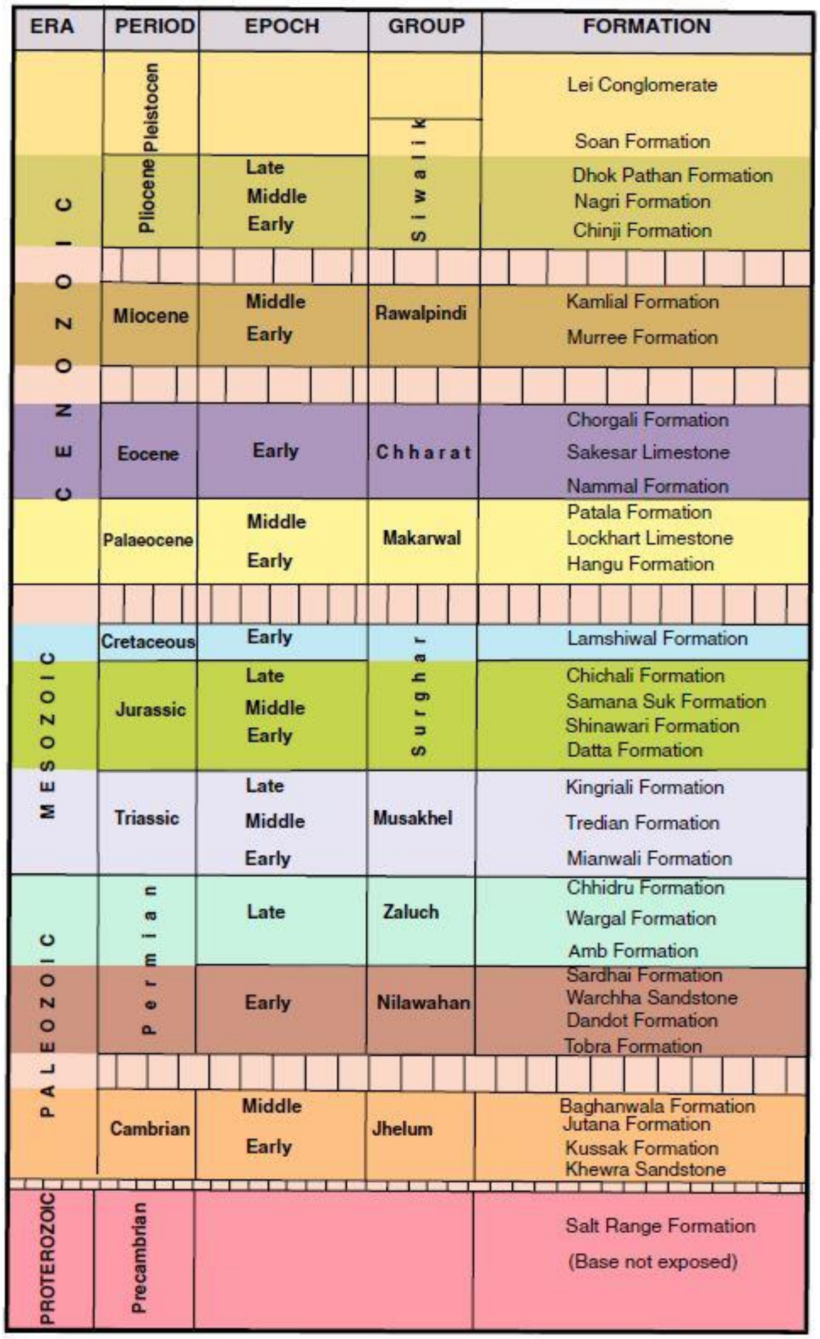

Figure 2: Generalized Stratigraphic succession for the study area after Ghazi et al., 2014).

3. Methodology

Groundwater samples were collected for physico-chemical analysis from 50 locations shown in figure 1 within the urban settlements of Khushab city during September 2014. The samples were collected during the pumping operation and were kept in the polyethyene bottles of 500 ml capacity. These bottles were pre-cleaned in order to remove trace impurities within the bottle or from the walls of the bottles. All samples were properly sealed, labelled, showing the source date and time of the sample collection. Standard procedures (APHA,1995) were applied to analyse the ground water samples. pH, electrical conductivity (EC) and total dissolved solids (TDS) were few physical parameters investigated in the present study.

3.1 pH & EC measurement

In situ analysis of pH and electrical conductivity (EC) was carried by using portable digital pH meter and conductivity meter, respectively. pH was measured through US based pH meter model 9932 Hanna, while the conductivity meter model 4510 EC Jenway, UK was used for EC measurements.

3.2 TDS measurement

Total dissolved solid (TDS) is a physical parameter directly related to EC. Therefore, TDS values were calculated by multiplying the values of EC by 0.69. Salinity hazard from the investigated water samples was evaluated by using EC following the research conducted by Richards (1954). Moreover, water samples were classified on the basis of TDS following the work of Davies and De Wiest (1966). Major ions like chloride, magnesium and calcium were analyzed by means of Ethylene diaminetetraacetic acid (EDTA) titration. Argentometric titration (AgNO3) was used for the concentration of Cl- in water samples. Salicylate method was used to analyze concentration of NO3- following the recommendations of (APHA,1995).

3.3 TH measurement

Total hardness (TH) was also determined by using the calcium and magnesium ions concentration in the water samples. Water samples wereclassified on the basis of (TH) into different categories i.e. from fit to unfit on the basis of work done by Sawyer and McCarthy (1967). Spatial distribution of variabilty of different physico-chemical parameters within the study area was analysed by using ARC GIS 9.3 tool. Impact of water quality on health of people was also assessed. The relation between water quality and health of the residents of the study area was established by using the data from District Headquarter Hospital Khushab highlighting frequency of different waterborne diseases in the study area. A survey was also conducted to know the public awareness regarding change in water quality form the last decade. Various questions were raised regarding general know how of the people to towards the issue.

4. Result and Discussion

The summary of physico-chemical data from the 50 selected sites with minimum, maximum, mean and standard deviation values is given in Table 2. In addition to Table 2, details of physico-chemical parameters with their corresponding latitude and longitude of Khushab city are given in Table 3. The concentration of hydrogen ion (pH) ranges from 6.8 and 8.7 with an average of 7.62 showing it mildly alkaline in nature.16% of the samples showed deviation from the upper limit of WHO standards (Figure 3b). Depending upon pH, groundwater of Khushab city is mildly alkaline in nature.

The electrical conductivity (EC) of groundwater samples from the study area varies between 260 and 10290 μS/cm with an average of 3378.2 μS/cm. Graphical representation for the EC results are shown in Figure 3 (a) which indicates that 42% of the samples show values more than 2200 μS/cm. Richards classification scheme was used for evaluating salinity hazard for irrigation on the basis of EC values which showed 58% of the samples as poor for irrigation (Table 4). Study area shows relatively higher salinity because of dissolving the salts from the soil in the locality along with the addition of fertilizers used in the crops in the vicinity of the urban settlements of Khushab city.

Total dissolved solids (TDS) is another important parameter as it highlights the concentration of contaminant in the water samples. EC has a direct relation with dissolved solids therefore TDS was calculated by using mathematical relation TDS = 0.69EC. The nature and grade of dissolved matter in the water samples is based on the chemical configuration and physical structure of the rocks, along with the pH value in the vicinity of aquifers (Sajil Kumar et al. 2014). TDS ranges between 179 and 9410 mg/l with an average of 2425.66 mg/l as shown in Figure 4 (b). Table 5 shows that on the basis of TDS 38 percent of the samples were considered fit and permissible for drinking and irrigation, 26% samples were considered unfit for drinking but suitable for irrigation while rest of the 36% samples were considered neither fit for drinking nor irrigation.

Concentration of Ca^+ ions ranges between 1.2 and 11.8 mg/l while Mg^+ have concentration ranges between 0.3 and 39.4 mg/l (Figure 5a and 5b). The average values for Ca^+ and Mg^+ were very low i.e. 3.89 and 8.25 mg/l respectively. All groundwater samples showed that concentration of Ca and Mg are even less than the lower limit of WHO desirable standard i.e. 75 mg/l for Ca and 30 mg/l for Mg (Table 2). Presence of calcium and magnesium in groundwater samples is because of dissolution of carbonates ions which occur in clay beds and lenses close to the aquifers with in the study area. Hardness of water is described as the concentration of mettalic ion which makes it unfit for drinking purpose. Hardness can be either permanent or temporary hardness. Temporary hardness is due to the presence of $CaCO_3$ and can be removed by boiling the water while permanent hardness is due to the concentration of calcium, magnesium, sulfates and chloride ions. Ion exchange method process is used to remove the permanent hardness from water.

In the present study total hardness (TH) from the water samples was calculated by substituting the concentration of Mg and Ca (mg/l) by using the Eq.1 equation:

$Total\ Hardness\ (TH) = 2.5(Ca^{2+}) + 4.1(Mg^{2+})$ (Eq.1)

Total Hardness = 2.497 (Ca^{+2}) + 4.115 (Mg^{+2})

TH values showed much variability ranging between 6.23 and 216.86 mg/l with an average value of 43.45 mg/l (Figure 4 a). Water samples were classified on the basis of total hardness (TH) using work done by Sawyer and McCarthy (1967) as shown in the Table 6. According to the Table 6, 78% samples were considered as soft, 18% were considered as moderately hard while 4 % were considered as hard. Concentration of Cl^- ions found highly variable ranging between 0.3 and 344.7 mg/l with an average of 34.74 mg/l (Figure 6 a). According to WHO standards desirable range of Cl^- is up to 250 mg/l. Only 6% of the samples showed values higher than desirable range. Presence of higher chlorine concentration is directly related to the anthropogenic activities and infiltration of sewage pollutants into shallow aquifers (Umar and Ahmad, 2007). Concentration of NO^{3-} was also variable within the study area i.e. 12 and 62 mg/l (Figure 6 b). According to WHO standards for drinking water NO^{3-} values should not exceed 50 mg/l. High NO^{3-} values are mostly observed in surface and ground water due to the extensive use of fertilizers and urea (Sakizadeh et al., 2015). This fact was completely in accordance to the results obtained from water samples. 12% of the total samples showed deviation from WHO standards for drinking water out of which 8% samples were close to the outskirts of the city where nearby areas are used for cultivation of crops and extensive use of fertilizers is observed.

Arc GIS 9.3 tool was used to study the distribution of all the physico chemical parameters with in the urban settlements of Khushab city. Green colour in the spatial distribution map shows value of the parameter within the WHO standards while red colour in the map indicates the value of the parameter is out of WHO standard permissible range. Figure 7 (a,b,c) are showing the spatial distribution of pH, EC and TDS respectively in the urban settlements of Khushab city. pH values in investigated samples show deviation in the central, north western and north eastern parts of the study area (Figure 7a). Since EC and TDS are directly related to each other that is why the spatial distribution of these parameters is almost the same. Most of the samples are deviating from the upper limit of WHO standards. The samples which lie within the WHO standards were either towards the southern part or towards the northern part of the study area (Figure 7b and 7c). Ca and Mg are within the desirable range of WHO standards throughout the study area. That is why the spatial distribution map is in green colour showing the parameters safe for drinking purpose (Figure 8a and 8b). Spatial distribution map for NO^{3-} showed that most of the samples which deviated from the WHO standard values were in the outskirt of the urban settlements of Khushab city Figure 9a). Although very few samples showed deviation of Cl^- ions from the WHO standards mostly but those samples were also collected from the central parts of the study area. ARC GIS maps showed that most of the samples which showed deviations in different physico-chemical parameters were collected from the central parts of the study area (Figure 9b). It is important to mention that central part of the study area is most densely populated. Therefore, direct anthropogenic activities can be one of the main reason for the decline in water quality mostly within the central parts of the study area.

Consumption of contaminated water is a serious cause of health issues in developing countries (Rasoloariniaina et al., 2015). Human beings are affected and infected by highly impure water. It may have an impact on different organs and can cause physiological disorder. For instance, hard water is unfit for domestic uses and is also not suitable for agriculture and industry (Patil et al. 2012). pH values below or above WHO standards can affect mucous membrane and taste buds. Hard water can casue digestion problems while high EC and TDS values cause gastro-intestinal issues. Joint stiffness, hardening of arteries, kidney and gallstones are some of the severe impacts of high levels of TDS in the drinking water (I. Hussain et al., 2014).

Table 2: Statistical summary of groundwater samples collected from Khushab city (pH has no units; Units of EC are mg/l is the unit for other parameter).

	EC	TDS	Mg	Ca	pH	Cl	NO_3	TH
Min	260	179	0.3	1.2	6.8	0.3	12	6.23
Max	10290	9410	39.4	11.8	8.7	344.7	62	216.8
Mean	3378.2	2425.6	8.25	3.89	7.62	34.74	31.0	43.4
SD	2702.4	2171.1	9.86	2.52	0.54	76.9	13.3	43.3
n	50	50	50	50	50	50	50	50
WHO (1993)	1000	1000	30	75-150	6.5-8.5	250	50	500

Table 3: Physico-chemical parameters from the collected groundwater samples from the study area.

Site. ID	Latitude	Longitude	EC µS/cm	TDS mg/l	Mg^+ mg/l	Ca^+ mg/l	pH	Cl^- mg/l	NO_3^- mg/l	TH mg/l
S1	32°17'40"	72°19'52"	5200	3588	9.9	5.6	7.6	22.2	36	54.71
S2	32°17'27"	72°19'32"	2370	1635	4.5	3.0	7.7	16.1	35	25.98
S3	32°17'61"	72°20'21"	4750	3277	6	5.2	7.7	24.2	31	37.67
S4	32°17'83"	72°20'05"	3810	2628	5.3	3.6	7.8	23.5	39	30.79
S5	32°17'34"	72°20'08"	350	241	0.8	2.2	7.7	0.6	38	8.78
S6	32°17'05"	72°20'15"	10290	7620	51	2.8	8.6	328.4	54	216.86
S7	32°17'13"	72°20'48"	3980	2746	7	5.0	7.9	25.4	34	41.29
S8	32°17'81"	72°20'34"	4150	2863	2	2.8	8.7	22.5	31	15.23
S9	32°17'28"	72°20'55"	4090	2822	7.9	4.4	7.9	25.1	34	43.50
S10	32°17'45"	72°20'90"	310	213	0.4	2.0	7.6	1.4	33	6.46
S11	32°17'63"	72°20'51"	260	179	0.3	2.0	7.0	1.3	23	6.23
S12	32°17'12"	72°21'42"	2860	1973	10.8	2.8	7.5	14.5	42	51.44
S13	32°17'09"	72°21'45"	7980	5506	20.6	9.4	8.65	43	59	108.24
S14	32°17'33"	72°20'87"	4130	2849	6	2.0	8.7	16.4	62	29.68
S15	32°17'41"	72°20'24"	3270	2256	5.3	5.2	7.7	19.2	31	34.80
S16	32°18'17"	72°20'44"	1770	1221	2.8	7.0	7.5	10	34	29.00
S17	32°18'65"	72°20'53"	370	255	0.6	2.4	7.7	0.6	41	8.45
S18	32°18'69"	72°20'55"	630	434	2	2.8	7.7	1.8	31	15.3
S19	32°18'44"	72°20'48"	500	345	0.9	2.8	7.7	2.1	30	10.70
S20	32°18'51"	72°20'01"	2350	3691	14.2	6.4	7.4	22.4	21	76.11
S21	32°18'88"	72°20'25"	5370	3705	14.5	6.2	7.5	26.4	22	76.23
S22	32°18'39"	72°20'57"	2970	2049	1.7	1.6	7.9	15.6	43	11.00
S23	32°18'37"	72°21'33"	7390	5099	19.8	8.0	8.7	39.2	57	101.4
S24	32°18'59"	72°21'72"	4370	3015	2.4	1.6	8.6	24.4	51	13.87
S25	32°18'47"	72°21'56"	6230	4298	14.6	7.0	7.8	30	33	77.47
S26	32°18'79"	72°21'33"	4550	3139	39.4	1.8	8.61	28.2	54	166.8
S27	32°18'04"	72°21'63"	6820	4705	10.7	5.4	7.7	46.2	33	57.5
S28	32°18'85"	72°22'75"	1150	793	2.2	2.0	7.8	5.2	31	14.05
S29	32°18'60"	72°22'65"	4730	3263	2.2	1.8	8.64	28.8	56	13.55
S30	32°18'66"	72°22'89"	1150	794	2.6	1.6	7.8	5.0	32	12.2
S31	32°18'97"	72°21'80"	1410	972	0.6	2.4	7.2	4.3	22	8.46
S32	32°18'21"	72°21'61"	7060	1214	10.4	1.9	7.4	4.0	22	47.53
S33	32°18'23"	72°21'23"	6670	4602	10.7	4.8	7.7	40.2	33	56.00
S34	32°18'16"	72°21'21"	1450	1000	4.3	3.2	7.3	6.2	23	25.68
S35	32°17'32"	72°21'35"	9410	10632	19.8	11.8	7.2	322.4	22	110.93
S36	32°17'12"	72°21'55"	6730	4643	17	7.2	7.1	35.2	21	77.47
S37	32°17'20"	72°21'62"	5270	3636	15.7	2.0	7.0	30.4	13	69.59
S38	32°17'62"	72°21'92"	950	655	2.1	2.4	7.1	3.5	15	14.6
S39	32°17'29"	72°21'58"	6730	4643	17.7	6.2	6.9	33.9	14	88.31
S40	32°17'95"	72°21'39"	930	641	3	2.4	7.1	4.0	19	18.34
S41	32°17'28"	72°21'75"	900	621	1.5	2.8	6.8	1.8	12	13.17
S42	32°17'75"	72°21'51"	730	503	1.9	3.8	6.9	1.4	14	20.27
S43	32°17'36"	72°20'83"	780	538	3.3	2.4	6.9	2.0	15	19.57
S44	32°17'10"	72°20'61"	550	379	2.5	2.0	7.0	0.3	12	15.28
S45	32°17'60"	72°20'82"	2440	1683	7.5	4.1	6.9	11.2	13	36.60
S46	32°17'50"	72°20'49"	410	282	0.9	2.3	7.3	0.6	19	9.44
S47	32°17'05"	72°21'47"	370	255	1.9	1.2	7.6	10.1	27	10.79
S48	32°17'63"	72°20'17"	400	276	1	2.2	7.2	0.7	22	9.60
S49	32°17'79"	72°21'15"	5640	5575	18.7	11.4	7.4	344.7	39	105.41
S50	32°18'27"	72°20'22"	1930	1331	3.7	2.0	7.3	10.4	24	20.22

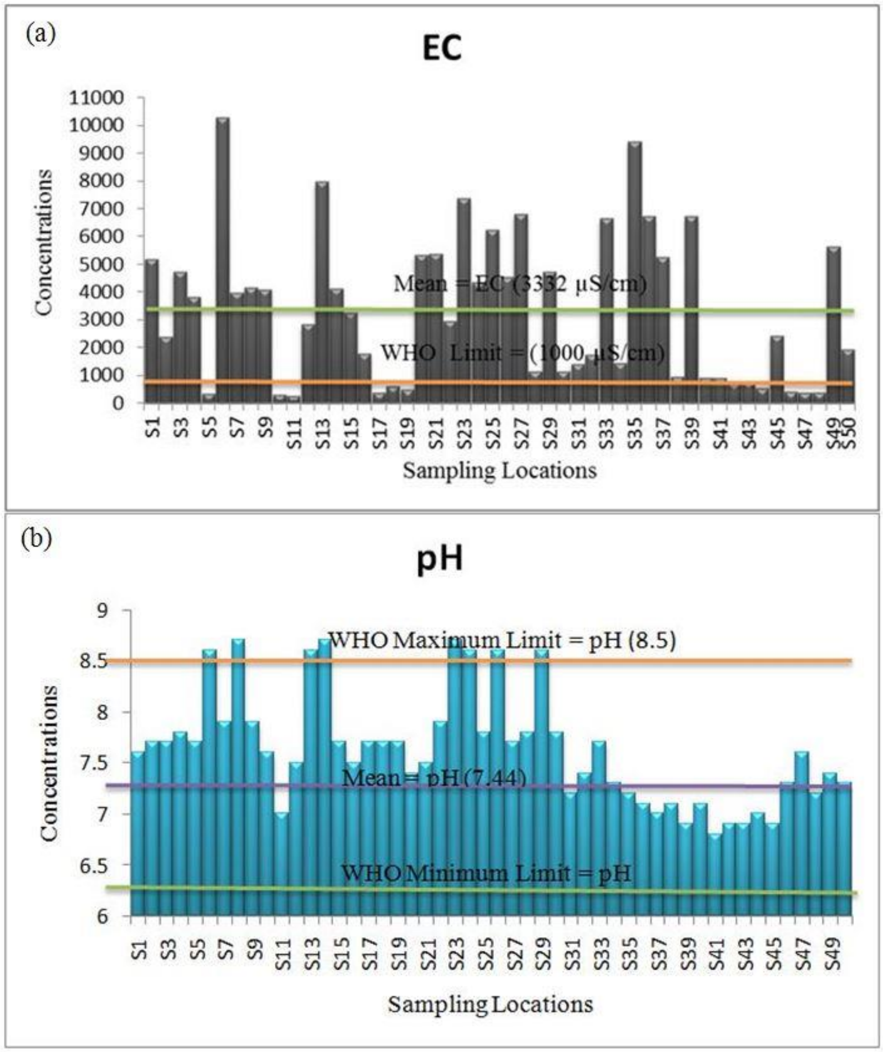

Figure 3: Graphical display of (a) electrical conductivity (EC) and(b) pH within the study area. Mean, WHO limits for these parameters are also shown.

Table 4: Irrigation water quality classification on the basis of EC (after Richards 1954).

Water Class	**Salinity Hazards**	
	EC	Number of samples (%)
Excellent	< 250	0
Good	250-750	7(14%)
Fair	750-2250	14(28%)
Poor	> 2250	29(58%)

Table 5: Classification of groundwater based on TDS (Davies and Wiest 1966).

TDS	**Water type**	**Percentage**
Up to 500	Desirable for Drinking	20%
500-1,000	Permissible for Drinking	18%
< 3000	Unfit for drinking but useful for irrigation	26%
> 3000	Unfit for drinking and irrigation	36%

Table 6: Classification of groundwater based on hardness (TH) after Sawyer and McCarthy (1967).

Total Hardness (mg/l)	Water Type	Percentage
< 75	Soft	78%
75-150	Moderately Hard	18%
150-300	Hard	4%
> 300	Very Hard	-------

Table 7: District Health Information System (DHIS) Report District Khushab for year 2014.

Sr. No	Diseases	Daily Patient	Monthly Patient	Yearly Patient	Local Patient	Outside Patient
1	Infection	6-8	230	2760	1256	1504
2	Suspected hepatitis	56	1680	20160	8536	11597
3	Diarrhea	13	393	4001	1800	2547
4	Dysentery	7	201	3127	981	1800
5	Gastro	4	118	1416	523	893
6	Scabies	8	95	1140	486	654
7	Kidney stone	3	24	274	123	154
Total	…..………	98	2941	32878	13705	19149

After the complete analysis of data sets and compilation of all results a survey was conducted to assess the people views and awareness related to the declining water quality within the study area. 100 permanent residents of the study area were interviewed and were asked different questions related to water quality in the study area. The survey showed that 62% of the interviewed persons were very much dissatisfied, 18% were somewhat dissatisfied, 15% were somewhat satisfied and only 5% were completely satisfied with the present-day water quality (Figure 10a). Moreover 80% of the interviewed people agreed that water quality has radically changed in the study area (Figure 10 b).

Similarly, Cl^- can cause stomach disorder, eye and nose irritation while nitrate values above WHO standards creat problems for new born babies e.g. blue-baby syndrome and shortnesss of breath. That is why results obtained from the study were also correlated to the health of the people living in Khushab city and its vicinty. Data for diffferent water borne diseases from District Head Quarter Hospital for the year 2014 was collected. According to the data provided by District Health Information System (DHIS) people residing in Khushab city and nearby areas are suffering from waterborne disease e.g. Infection, Hepatitis, Diarrhea, Dysentery, Gastro, Scabies and Kidney-stones. Table 7 highlights the number of patients suffering from waterborne diseases. 98 patients are visiting per day suffering from the above-mentioned diseases, similarly 2941 patients visit hospitals every month suffering from diseases related to water quality. On a yearly basis 32878 patients have registered complaints related to the waterborne diseases out of which 13705 patients are living within the study area while 19149 patients were residing on the outskirts of the study area.

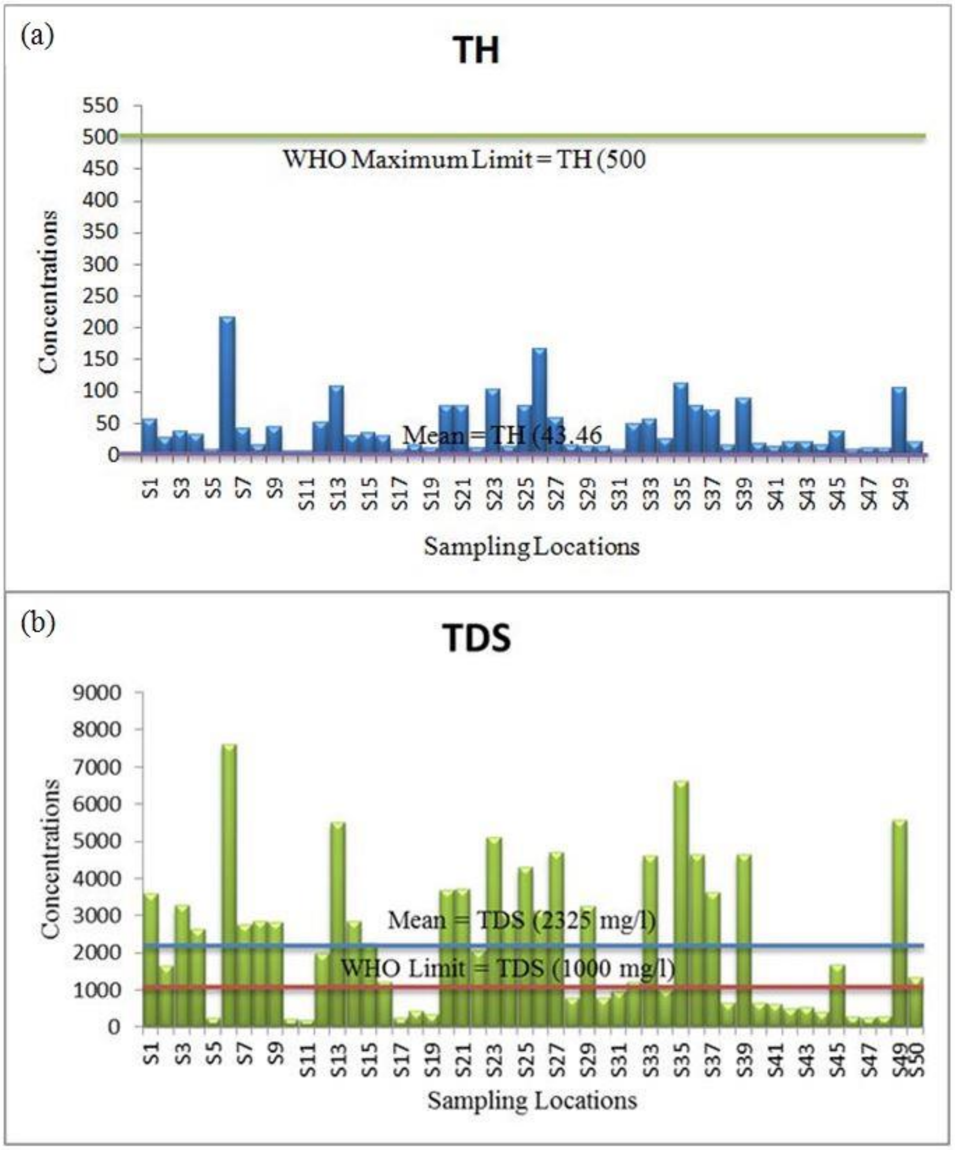

Figure 4: Graphical display of (a) TH (total hardness) and (b) TDS (total dissolved solids) within the study area. Mean, WHO limits for these parameters are also shown.

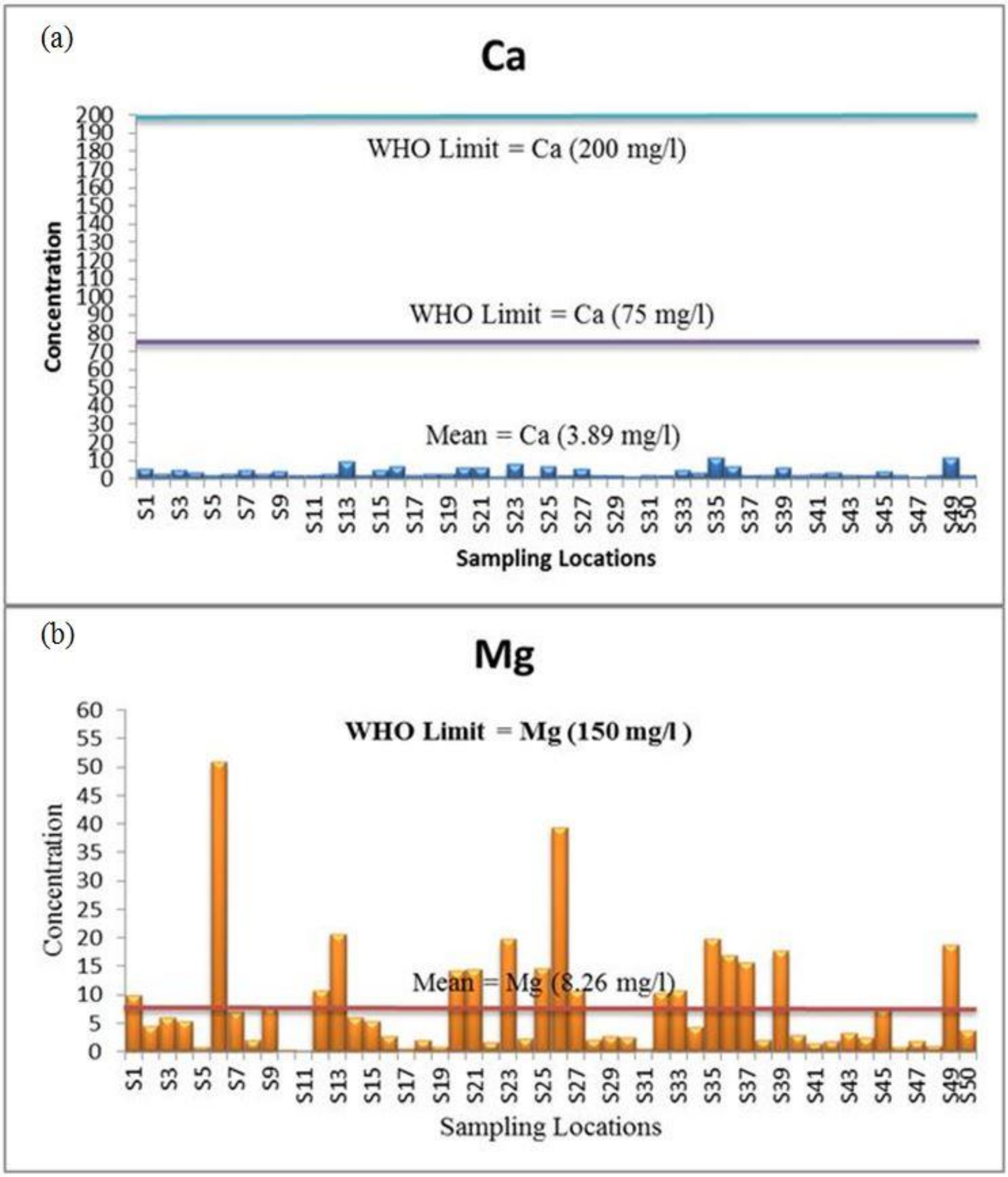

Figure 5: Graphical display of (a) Ca (Calcium) and (b) Mg (Magnesium) within the study area. Mean, WHO limits for these parameters are also shown.

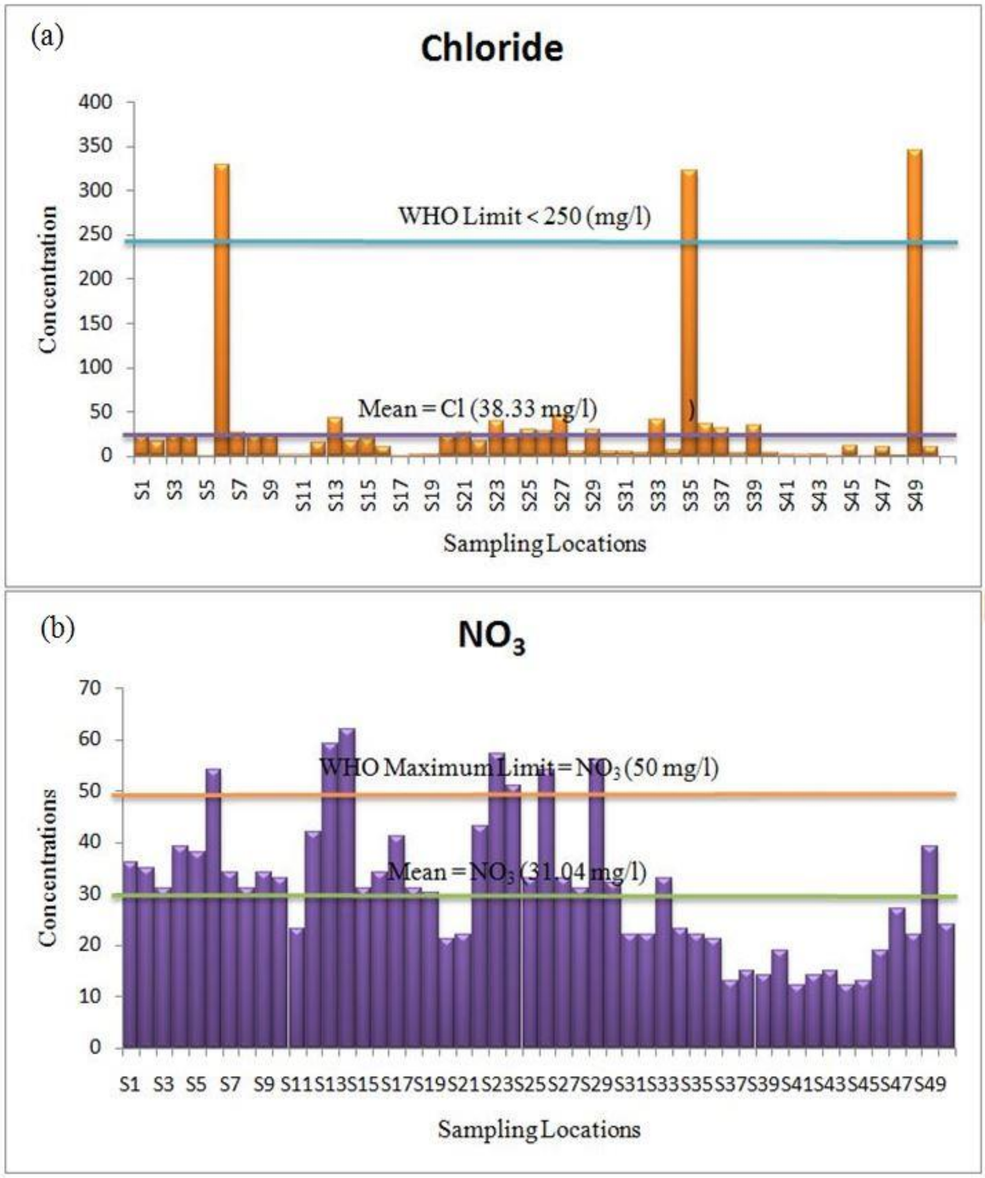

Figure 6: Graphical display of (a) Chlorine (Cl^-) and (b) NO^3 (Nitrates) within the study area. Mean, WHO limits for these parameters are also shown.

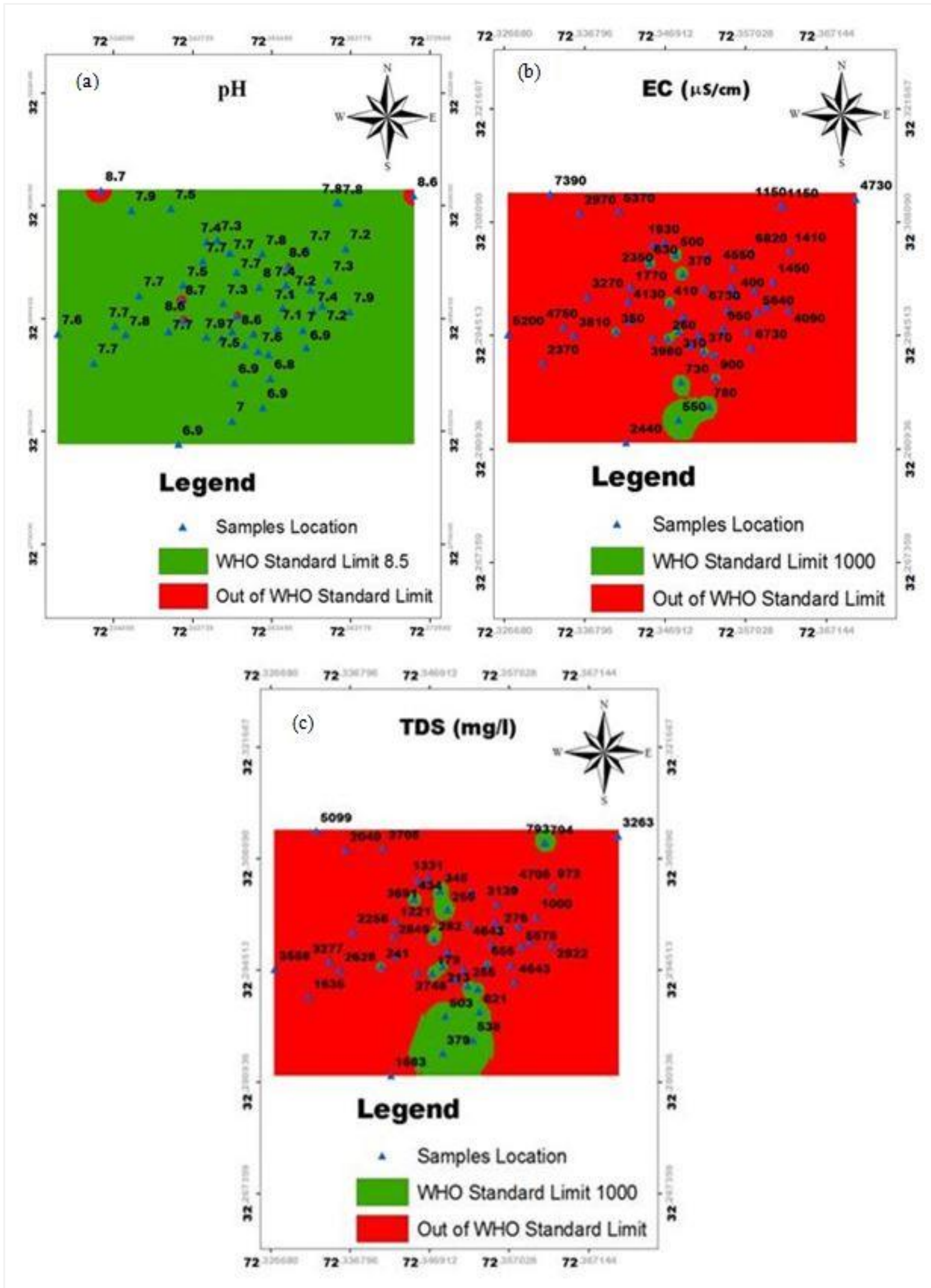

Figure 7: Spatial distribution of (a) pH, (b) EC and (c) TDS within the study area. Green colour shows the parameter within the WHO standard while red colour indicates the parameter is out of the WHO standard range.

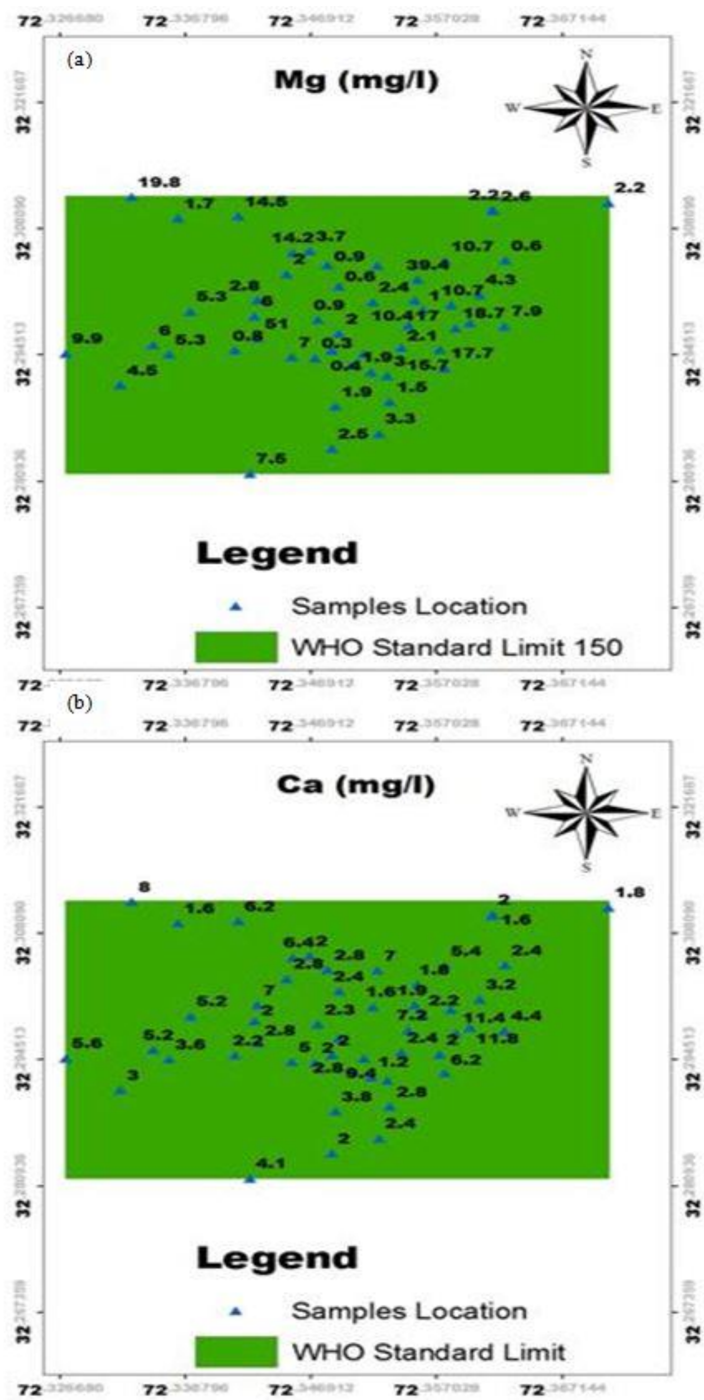

Figure 8: Spatial distribution of (a) Mg, (b) Ca within the study area showing both parameters are within the permissible WHO limits.

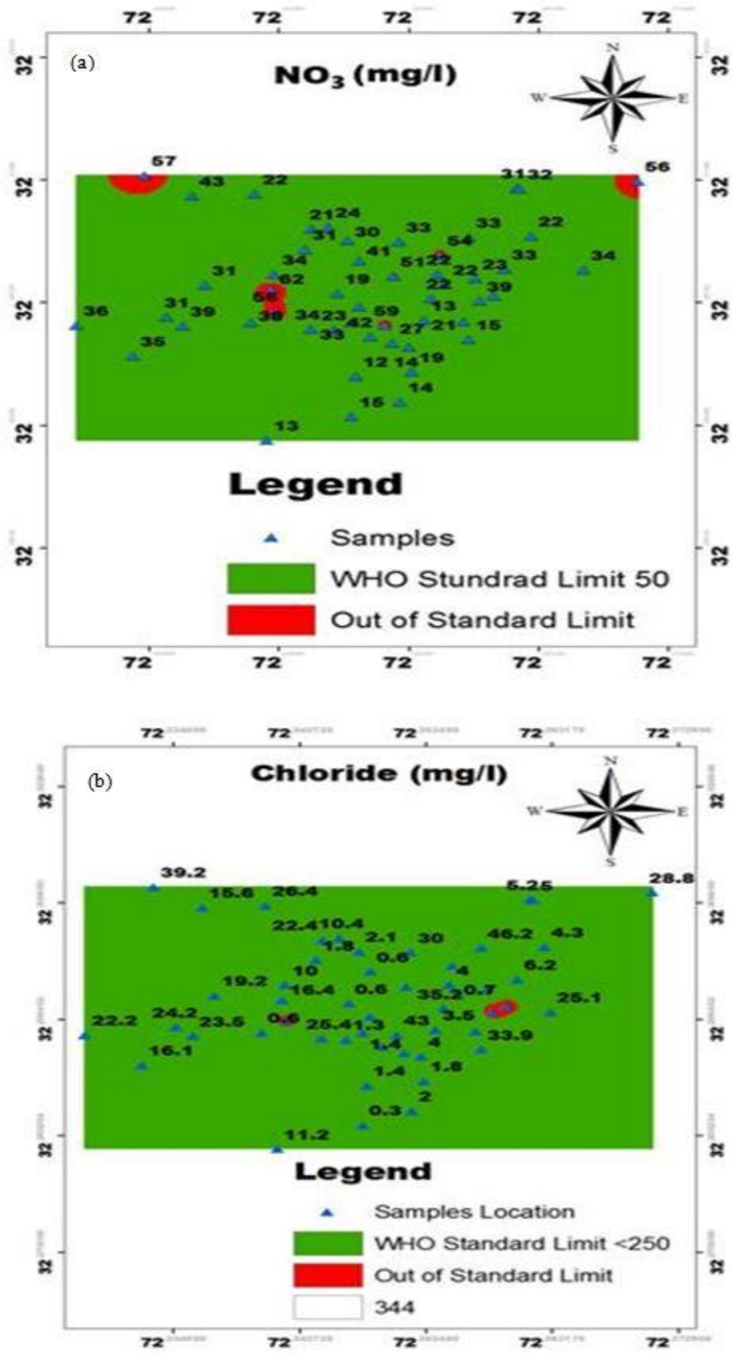

Figure 9: Spatial distribution of (a) NO^3, (b) Cl showing few sites out of WHO limit while most of the sites within the permisible WHO limits.

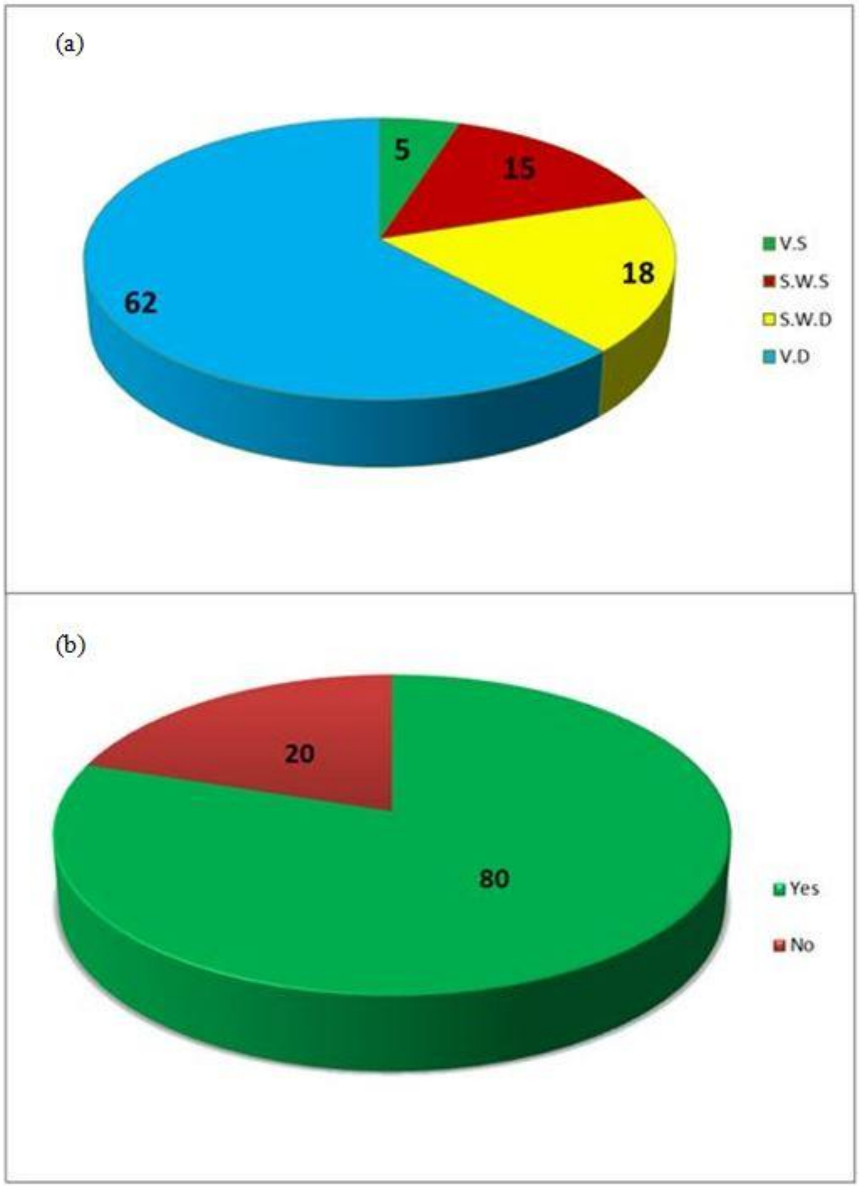

Figure 10: (a) Graphical display of the public response towards the interview conducted in the study area. V.S (Very Satisfied), S.W.S, (Somewhat Satisfied), S.W.D, (Somewhat Dissatisfied), V.D, (Very Dissatisfied). (b) Public views about change in the water quality within Khushab city during last decade.

5. Future planning and process development

The experimental results have determined that the total dissolved solids (TDS) and electric conductivity (EC) should be lowered and total hardness (TH), pH as well as salinity level should be improved for water quality development in terms of drinking and irrigation purposes. In order to improve the water quality, a set of water quality parameters and objectives would be determined, water purification modelling and actions list would be set up and implemented; salt, nutrients and good microbes would be added to the ground as per requirements, the effectiveness of purification treatments would be monitored for separate goals through indicators time-to-time; the most fruitful impact would be chosen and implemented for purification purposes; public awareness would be increased regarding minimization of indecomposable waste dump to the ground, proper management of household waste, reduction of chemical fertilizer usages such as urea and other ammonia based fertilizers and pesticides to the agricultural field, enhancement of bio-compost instead of chemical fertilizers etc. For the case of TH, pH and salinity improvement, it is recommended to add required amount of calcium carbonate ($CaCO_3$) and magnesium carbonate ($MgCO_3$) to the ground as they go to ground water and breakdown into ionic forms which are required for TH, pH and salinity fixation for this process. The chemical reactions are determined in Rc.1 and Rc.2. (Chilton, 1996; Davis, 2010; Sandi and Lamble, 2012).

$$CaCO_3 \rightarrow Ca^{2+} + O^{2-} + CO_2(g) \quad \text{(Rc.1)}$$

$$MgCO_3 \rightarrow Mg^{2+} + O^{2-} + CO_2(g) \quad \text{(Rc.2)}$$

A future planning on groundwater quality improvement strategy for Khushab city of Pakistan was proposed in Figure 11.

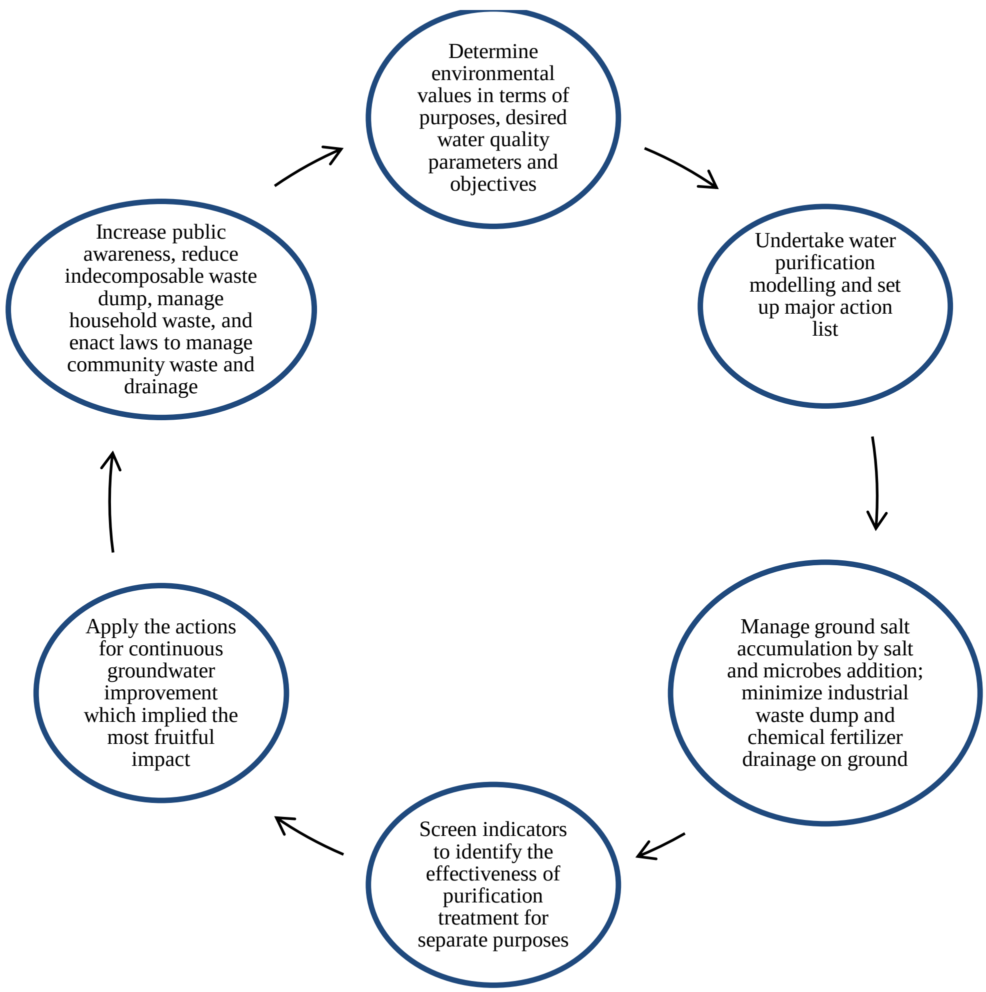

Figure 11: Future planning on process development for groundwater quality improvement in Khushab city of Pakistan (Sandi and Lamble, 2012).

6. Conclusion

The results obtained from 50 samples from Khushab city indicated alkaline nature of water with a high amount of electrical conductivity showing higher amounts of dissolved metallic ions and solids from the WHO standards. Although few parameters like calcium, magnesium and total hardness were within the WHO permissible range yet other parameters like Cl- and NO3- showed values exceeding the WHO limits at particular sites within the urban settlements of Khushab city. Residents of the study area were found suffering from various waterborne diseases e.g. infection, dysentery, diarrhea, cholera and hepatitis etc. Moreover, people belonging to the study area were mostly very dissatisfied from present the water quality and agreed to the fact that water quality has drastically changed within last decade.

The rapid urbanization has not only enlarged the size of towns and cities but also recharged water bodies and aquifers with polluted water, containing human and industrial hazardous contaminants. Therefore, in order to provide unpolluted water a continuous monitoring of ground water is essential. Moreover, state of the art purification treatment plants is the need of time, which can supply water to people fit for drinking and domestic purposes. Our proposed future planning on process development for groundwater quality improvement in Khushab city of Pakistan is highly recommended for the further steps to resolve the ground water pollution.

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