Risk assessment of heavy metals and salts for human and irrigation consumption of groundwater in Qambar city: a case study

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The study investigated the water quality of groundwater for consumption of human beings and irrigation of taluka Qamber district Qamber-Shahdadkot, Sindh, Pakistan. A total of 21 representative groundwater samples were collected mostly used for human consumption. According to the research work, 81% samples were not suitable for drinking purpose with TDS above the maximum permissible limit of WHO (1000 mg/L). The pH, total phosphate-P, orthophosphate-P, nitrate-N, nitrite-N, and arsenic were within WHO limits. The concentrations of essential metals more than half samples were higher than WHO guidelines. The concentrations of fluoride in 81% were higher than permissible limits of WHO. The high consumption of water with concentration of salts and fluoride above the permissible limits may be a leading factor of a number of diseases in the area.

The water quality determined for irrigation based on Kelly index (KI), sodium percentage (Na%), chloride–sulfate ratio, sodium adsorption ratio (SAR), permeability index (PI), chloroalkaline indices1 (CAI-1), residual sodium carbonate (RSC), and chloride bicarbonate ratio indicated that 25–90% samples were suitable for irrigation purposes.

1. Introduction

Water is absolutely essential not only for the existence of human life but also for plants, animals and all living organisms. Furthermore, it is essential that the required water should not comprise unwanted contaminations, harmful chemical substances or microorganisms (Raveneau & Burrough, 1988). Unfortunately, groundwater resources are being contaminated by various activities, mainly due to infiltration of pollutants into the soil sub-strata, site-specific quality like soil variety, aquifer depth, climate, period and recharge degree of an aquifer. These may affect the possibility and severity of a specific impurity in water (Satish Kumar, 2015).

In the last 50 years, the development of the groundwater resources has increased enormously and it is estimated that over 2 billion people worldwide depend on the groundwater for drinking purpose (Murali & Elangovan, 2013). The discharge of industrial, urban, and cultivated wastes has increased the chemicals that enter in the water, and may change their physicochemical properties. Responsible reflection of water quality in many sectors is the focus of concern of recent life. The water quality has remained focus in many sectors for the concerns for the human life, because the increase of the use of water in different processes. (Agarwal et al., 2012). Among many sources of the water, groundwater is considered safe for drinking but agriculture, industries and public requirements are polluting to the groundwater. Therefore, the availability of fresh groundwater is necessary for a large number of inhabitations (Abbulu., 2013; Anurag et al., 2010).

The contamination of groundwater due to the all reactions and processes water faces from moment it condensed in environment to time it is discharged by the hand pump or well and it varies from place to place with its depth. The major part of the rural populations depends on the groundwater due to the unavailability of water supply and treatment of clean water. In total, 40% of deaths in Pakistan are due to the water-borne diseases indirectly or directly (Tariq, Shah, Shaheen, Jaffar, & Khalique, 2008).

A lot of research has been carried out on the groundwater and on its suitability in the different areas of Pakistan Majidano et al., (2010) analyzed...
the physicochemical parameters of ground and surface water of taluka Nawabshah, Sindh. Samina et al., (2004) examined the physicochemical parameters of groundwater of Hazara strip, Pakistan. Kandhro et al. (2015) reported the physicochemical quality of ground and surface water for consumption purpose of the Nawabshah city, Sindh. Aziz-Ur-Rahman and Khan (2000) examined the drinking water quality of the urban parts of the Peshawar city, Pakistan part 1: Tube well water. Khan et al., (2005) examined the potable water characteristics of the urban parts of the Peshawar city Pakistan part 2: well water. Lodi–Ii, Akif, and Kasoom (2003) evaluated the drinking water from several sources in the Skardu-Norther parts and analyzed the heavy metals present in the water. Khan et al. (2000) examined the quality characteristics of drinking water of the Mardan city and its surrounding areas, Pakistan. Majidano, and Khuhawar (2008) reported the physicochemical quality of ground and surface water of Nawabshah taluka, district Nawabshah, Sindh, Pakistan. Majidano et al. (2010) analyzed the quality of ground and surface water of Daur taluka, District Nawabshah, Sindh, Pakistan. The results of the examination would make environmental awareness to people of the study area.

The present results of groundwater of taluka Qamber of district Qamber-Shahdadkot showed that about 80% of samples were not suitable for human consumption.

2. Materials and methods

2.1. Study area

2.1.1. Geography

The taluka Qamber is located at latitude 27.5859189 and longitude 68.0060183. The border of taluka Kamber is only 12 km away from Larkana city. The area of taluka Qamber is divided into two parts: one is Kohistan area (Western tract) and the other is chief canal irrigation area. The western parts of the taluka contain irregular topography of mountains and uplands comprise of the Kohistan part. The range of mountains and lime stone hills are denoted by the “Halar” but commonly known as Khirthar range spread along the total western border of taluka Qamber which extents to 19–21 km in the straight line. The range of Khirthar contains of an uphill series like Pinaro (saffron color), Karo (Black) and Kakrio (Broken). The maximum high peak known as Dog’s Grave and in Sindhi known as Kuti-ji-Kabar which is 2065 m higher than sea level and 300 m higher than adjoining area. The world famous Khirthar mountain crosses from western boundary of taluka Qamber. Approximately, 35% area of taluka Qamber is under agriculture but 65% area covers lakes, foothills, ponds, etc. The famous lakes like Hamal, Drigh, Saroh and Chagro are present in the taluka Qamber. The chief crops of the area are rice and wheat but some crops sorghum sesame, maize, etc., are also found here (Chandio & Anwar, 2009).

Population and climate

The total population of taluka Qamber is 395,206 according to the 2017 consensus.

Taluka Qamber is one of the hottest areas of Sindh province; the reported maximum temperature is 124.88°F in July 2002. The three months, May, June and July, are hottest months of the taluka Qamber (Chandio & Anwar, 2009).

2.2. Samples collection

The taluka Qamber district Qamber-Shahdadkot was selected for the research work because of being remote area of Sindh Province and less investigated. The total 21 samples were collected from August 2015 to May 2016 (Table 1). Representative samples were collected from the town and populated villages to cover most of the areas where the groundwater is used for human consumption and irrigation. The water samples were collected from hand pumps and tube wells. The approximate depths of pumps and wells were noted. The water samples were collected in 1.5 L clean plastic sampling bottles after the pumps were allowed to drain for 5 min before collection of the sample. Two bottles were collected from each sampling site: one for physicochemical analysis and the other for metal analysis. The bottle for metal analysis was acidified with 1 mL of hydrochloric acid/nitric acid.

2.2.1. Sample preparation and preservation

The samples at the site were analyzed for conductivity, total dissolved salts and salinity. The samples were transferred to laboratories and were analyzed for the contents of pH, chloride, hardness and alkalinity, nitrate, nitrite, total phosphate, orthophosphate, sulfate, chemical oxygen demand (COD), sodium, potassium, calcium, magnesium, arsenic, fluoride, copper, manganese nickel, cobalt, iron, cadmium, lead and chromium. The analyses were carried out using standard analytical procedures based on spectrophotometry, atomic absorption spectrophotometry and electrochemical techniques. The electrical conductivity (EC), total dissolved solids and salinity were analyzed using Orion 115 conductivity meter and pH was analyzed using Orion 420A pH meter.

Chloride, hardness and alkalinity were analyzed by the titrimeetry method (American Public Health Association [APHA], American Water Works Association, Water Pollution Control Federation, & Water Environment Federation, 1913).
Table 1. Name of villages sampled from taluka Qamber with GPS reading.

| S. ID | Name of towns and villages       | Depth foot | Source of water | Latitude | Longitude |
|-------|----------------------------------|------------|-----------------|----------|-----------|
| 1     | District Court                   | 55         | Hand pump       | 27°34.24 | 67.59.46  |
| 2     | Civil Hospital Qamber            | 55         | Hand pump       | 27°35.03 | 67.59.64  |
| 3     | Hussain Shah Chock               | 60         | Hand pump       | 27°35.16 | 68.00.04  |
| 4     | Shaheed Yadgar Chock Qamber      | 50         | Hand pump       | 27°35.23 | 67.00.16  |
| 5     | Shahdadkot Road Qamber           | 60         | Hand pump       | 27°36.02 | 67.59.52  |
| 6     | Ali Khan Mahla                   | 55         | Hand pump       | 27°36.06 | 67.59.52  |
| 7     | Larkana Shahdadkot Chock Qamber  | 50         | Hand pump       | 27°35.23 | 68.00.17  |
| 8     | Ghebidero Chock Qamber           | 60         | Hand pump       | 27°35.37 | 67.59.56  |
| 9     | H.B Petrol Pump                  | 50         | Hand pump       | 27°33.27 | 67.59.56  |
| 10    | Village Akram Khan Lanjwani      | 50         | Hand pump       | 27°33.27 | 67.59.56  |
| 11    | Ber Shareef                      | 60         | Hand pump       | 27°32.37 | 67.57.10  |
| 12    | Gataher                          | 60         | Hand pump       | 27°32.08 | 67.57.46  |
| 13    | Thori Bajar                      | 55         | Hand pump       | 27°32.08 | 67.57.46  |
| 14    | Noor Mohd: Sheikh                | 50         | Hand pump       | 27°32.08 | 67.57.46  |
| 15    | Heesab Magsi                     | 55         | Hand pump       | 27°32.08 | 67.57.46  |
| 16    | Mohd: Ali Panhwar                | 55         | Hand pump       | 27°32.08 | 67.57.46  |
| 17    | Ghebidero                        | 60         | Aaro plot       | 27°34.46 | 67.45.20  |
| 18    | Kot Nawab                        | 50         | Tube well       | 27°32.89 | 68.00.29  |
| 19    | Ghogharo                         | 50         | Hand pump       | 27°32.89 | 68.02.44  |
| 20    | Pakho                            | 55         | Hand pump       | 27°32.89 | 68.02.44  |
| 21    | Khairpur Juso                    | 50         | Hand pump       | 27°32.89 | 68.02.44  |

The sodium (Na⁺), potassium (K⁺), calcium (Ca²⁺) and magnesium (Mg²⁺) were analyzed by using flame atomic absorption spectrophotometer (AA-800 Perkin Elemer, Singapore) at 589.0 nm, 766.5 nm, 422.7 nm and 285.2 nm, respectively, and heavy metals Cr, Mn, Fe, Co, Ni, Cu, Cd and Pb were analyzed by using flame atomic absorption spectrophotometer (Perkin Elemer, AA-800, Singapore) as per the manufacturer’s instructions. The analysis was carried in triplicate (n = 3) with integration time 4 s and delay time 4 s. A computer with Winlab software controlled the instrument. For the analysis of Na, K, Ca, Mg, samples were appropriately diluted 10 – 25 times with deionized distilled water, whereas for analysis of trace elements, the samples were concentrated 10 times by evaporation of the water at 80 – 90 °C on electrical hot plate. The solutions were filtered and kept cool till analysis (APHA, 1995).

The spectrophotometric studies were carried out on Hitachi 220 double-beam spectrophotometer (Hitachi Pvt. Ltd, Tokyo, Japan) with dual 1 cm silica cuvettes.

The basic statistics such as minimum, maximum, mean and standard deviation of the parameters were calculated (Table 2). Correlation coefficient (r) between physicochemical parameters and metal ions were calculated by using Microsoft Office Excel 2013. The software program SPSS 22 (SPSS Inc., Chicago, IL, USA) was used for the validation of the results. The multivariate analysis was also used for the hierarchical cluster analysis and principal component analysis using software SPSS version 22 and Piper diagram was drawn with help of Aquachem software.

The results of analysis were used to calculate different parameters to evaluate the suitability of groundwater for irrigation. The fluoride was analyzed by ion-selective electrode method using Hanna H1 2216 bench top pH/ORP/ISE multimeter connected with fluoride ion-selective electrode. The arsenic was determined by MERCK test kit (low range 0.05–0.300 mg/L) (Merck, Germany) as per the manufacturer’s instructions.

COD were determined by using an open reflux method (Apha, 1992). Then, took 5 mL of water sample in 100-mL refluxing flask and 0.2 g of HgSO₄ was added, followed by 4 mL of AgSO₄ solution. Then the solution was cooled. After cooling, 3 mL of K₂Cr₂O₇ was added followed by 3 mL of

Table 2. Minimum, maximum, mean and standard deviation values of parameters.

| Parameters       | Minimum (n = 21) | Maximum (n = 21) | Mean (n = 21) | Standard deviation (n = 21) |
|------------------|-----------------|-----------------|--------------|-----------------------------|
| pH               | 7.21            | 8.38            | 7.87         | 0.36                        |
| Conductivity (µs/cm) | 497             | 11,580          | 3921         | 3046.86                     |
| TDS (mg/L)       | 318             | 7411            | 2626.8       | 1950.12                     |
| Chloride (mg/L)  | 28              | 2819            | 737.52       | 791.86                      |
| T hardness (mg/L)| 150             | 1600            | 537.59       | 354.01                      |
| Alkalinity (mg/L)| 150             | 520             | 327.39       | 100.46                      |
| Sulfate (mg/L)   | 11              | 1441            | 513.74       | 413.10                      |
| Sodium (mg/L)    | 25              | 1186            | 336.95       | 278.84                      |
| Potassium (mg/L) | 6               | 117             | 24.39        | 23.18                       |
| Calcium (mg/L)   | 27              | 590             | 219.39       | 155.98                      |
| Magnesium (mg/L) | 18              | 557             | 147.78       | 134.96                      |
| Fluoride (mg/L)  | 0.39            | 21.80           | 6.90         | 6.42                        |
H₂SO₄ and few boiling chips. The solution was refluxed for 2 h on hot plate. After 2 hours, the solution was diluted twice of its volume with deionized water and cooled. Then the mixture of K₂Cr₂O₇ was titrated against 0.01 N ammonium iron sulfate in the presence of ferroin as indicator. The color turned green blue to reddish brown at the end point. The blank was measured following the same procedure with deionized water.

3. Results and discussion

The 21 groundwater samples were collected from taluka Qamber. Two samples were collected from tube wells and 19 samples from hand pumps. Nine samples were collected from Qamber city and 12 samples from different villages of taluka and analyzed for 28 parameters pH, EC, TDS, salinity, Cl, alkalinity, total hardness, COD, SO₄²⁻, NO₃⁻N, NO₂⁻N, TPO₄³⁻, P, OPO₄³⁻, P, essential metals like Na⁺, K⁺, Ca²⁺ and Mg²⁺ and metals like Cr, Cd, Mn, Fe, Co, Ni, Cu, Pb and toxic elements like As and F. Each of the determination was carried out in triplicate (n = 3) and average value is reported.

3.1. Physicochemical analysis

The pH value determined the strength of alkalinity or acidity of the water solution measured on the basis of −log of H⁺ concentration (Trivedy & Goel, 1984). The pH values of the study area were found to be in the range of 7.21–8.38, and the pH of all samples were within WHO limits 6.5–8.5 (World Health Organization [WHO], 2012). Majidano et al. (2010) reported the pH value ranging from 6.64–8.18 groundwater samples of Daur, Nawabshah district, province Sindh. The results were found to be in good agreement with those obtained in the current study.

The EC is used to determine the capability of water to carry electric current (Jameel, 2002). EC of study area were observed between 497 and 11,580 µS/cm. The EC of 4 samples were within and 17 were above the permissible limits of WHO (2012) (1500 µS/cm). The high concentration of EC is due to the soluble salts, ionic species and other soluble species present in the groundwater of the study area.

The total dissolved solids are due to the elements, minerals, salts, anions and cations dissolved in the water sample. The high concentration of total dissolved solids can cause stomach irritation and long time use can cause heart diseases and kidney stones in humans (Jain, Kumar, & Sharma, 2003). The TDS of the study area were found to be between 318 and 7411 mg/L, with an average value of 2626.8. TDS of 17 samples were above and only 4 samples were within the permissible limits of WHO (2012) (1000 mg/L). The higher values of TDS may be due to the geological nature of the soil present in the groundwater of the study area (Figure 1).

The total hardness is due to the calcium and magnesium and other metals present in the water (Jayalakshmi et al., 2011). The total hardness was observed between 150 and 1600 mg/L. The total hardness of 42.85% samples were above the maximum permissible limits of WHO (2012) limits (500 mg/L) (Shehzadi et al., 2014 reported variation in total hardness from 165 to 990 mg/L from district Muzaffarabad, Punjab, Pakistan. The result is slightly lower than current work).

The most important groundwater contaminants include nitrate NO₃⁻ and NO₂⁻. Nitrate in water originates from fertilizers, septic systems and industrial effluents. The WHO limit of nitrate in water is 10 mg/L. The excess level of nitrate is very toxic to

Figure 1. TDS of groundwater of study area.
infants because the bacteria in the infant’s digestive system can change the nitrate into nitrite. Nitrite can lead to most significant disease methemoglobin and can cause brain damage or even death (Gale et al., 1981). The nitrate and nitrite were observed between 0.36 to 11.57 mg/L and 0.12 to 4.03 µg/L, respectively, and could be due to the agricultural activities in the region. The nitrate of 2 samples were above the permissible limits and nitrite of all samples were within WHO (2012) limits (10 mg/L and 5 µg/L), respectively.

The phosphorus gets into water from manure, cultivated fertilizers, detergents, industrial wastages and organic substances. Phosphorus is essential elements of our human body, but its high concentration can cause health problems such as osteoporosis and kidney damage (Sittig et al., 1985). The $\text{TPO}_4^{3-} - \text{P}$ and $\text{OPO}_4^{3-} - \text{P}$ were observed between 0.093 to 0.58 and 0.005 to 0.246 mg/L, respectively, and were within the WHO limits (3 mg/L and 1 mg/L), respectively.

COD is a best indicator to measure the quality of the water. The high concentration of COD may be a concern of sewage pollution (Paul Supantha & Mishra Umesh, 2011). The COD results were observed between BDL and 41 mg/L. The COD of all samples were within WHO (2012) limits (50 mg/L), but it indicates some contaminations of groundwater with sewage water particularly from the town areas (Table 3).

### 3.2. Anions results

Alkalinity in water is due to the presence of carbonates, hydroxides or bicarbonate compounds. The weathering of sediments and other rocks are the main source of alkalinity in water. The high alkalinity in water gives a bitter taste, damaging soil and therefore decreases crop production (Sundar & Saseetharan, 2008). The alkalinity was observed between 140 and 520 mg/L as CaCO$_3$. The alkalinity of 9 samples were found within limits and 12 samples were found above the permissible limits of WHO (2012) (300 mg/L). Taj Muhammad (Jahangir., Khuhawar., Leghari., Mahar., & Khaskheli., 2013) reported alkalinity from 82 to 467 mg/L natural springs located in Thatta, Tharparkar, Jamshoro and Karachi districts of the Sindh province, Pakistan.

Chloride is present in both surface water and groundwater (Wara Rao, 2011). The chloride results were observed between 28 and 2818 mg/L. The chloride of 16 samples were found to be above and 5 within the permissible limits of WHO (2012) (250 mg/L). Majidano et al. (2010) reported that Cl$^-$ ranged from 41 to 13,953 mg/L groundwater of taluka Daur district Nawabshah.

Sulfate (SO$_4^{2-}$) is present in all natural water. The high concentration of SO$_4^{2-}$ can cause gastrointestinal irritation. If the concentration of sulfate is more than 600 mg/L in drinking water, it can cause cathartic effect (Sajil Kumar & James, 2013). The sulfate results were observed between 11 and 1075 mg/L. The SO$_4$ of 8 samples were within and 13 samples above the permissible limits of WHO (2012) (250 mg/L). Mahmood et al. (2014) reported that SO$_4^{2-}$ ranged from 93–161 mg/L of lower Sindh district Thatta season of monsoon and post-monsoon (Table 3).

### 3.3. Cations results

Sodium is a mineral found naturally in the earth crust and also in our drinking water. Sodium is one of the seven essential macro-minerals along with potassium, magnesium, phosphorus, calcium, chloride and...
sulfur. The human body needs sodium to maintain blood pressure, control fluid levels, and for nerve and muscle functioning. High blood pressure, stroke, cardiovascular disease, stomach cancer and kidney problem are occurred due to the high intake of sodium (Strazzullo, 2009). The sodium was observed between 25 and 1186 mg/L in the study area. The Na of 8 samples were within and 13 samples above the permissible limits of WHO (200 mg/L).

The natural water contains less amount of potassium than sodium. Potassium is very essential for the function of the heart, muscles, kidney, nerves, and digestive system. The high concentration of potassium causes hypertension and kidney problems (Dobrzański & Zawadzki, 1981). The results of potassium were observed between 06 and 117 mg/L in the study area. The K of 9 samples were within and 12 above the permissible limits of WHO (12 mg/L).

The source of Ca in water is gypsum, limestone and other Ca\textsuperscript{2+} comprising rocks, minerals and industrial waste (Karanth, 1987). Calcium and its compounds have low toxicity; however, a high calcium intake has been associated with kidney stone. The calcium results were observed between 27 to 590 mg/L. The Ca of 11 samples were within and 10 samples above the maximum permissible limits of WHO (2012) (150 mg/L).

Magnesium is an important mineral and cofactor in more than 300 enzyme systems that control various biological reactions in the human body, as well as protein, nerve and muscle functions, blood pressure and blood glucose regulator. The higher concentration of magnesium can cause vomiting, nausea, facial flushing, holding of urine, depression, weakness of muscle, breathing trouble and irregular heart beat disease (Musso, 2009). The magnesium results were observed between 18 and 557 mg/L (Table 4). The Mg of 11 samples were within and 10 samples above the maximum permissible limits of WHO (2012) (75 mg/L) (Figure 2). The cations and anions balance was calculated by adding cations (Na, K, Ca and Mg) and anions (Cl, HCO\textsubscript{3}, and SO\textsubscript{4}) in milliequivalent/L. The results of cations and anions agreed each other with error within 5% (Figure 3).

### 3.4. Trace and toxic elements

Chromium can enter the water supply in runoff from steel, paper mills, leather, dyes industry, municipal waste, corrosion of bushing and heaters or through the erosion of natural deposits chromite ore (Dixit & Tiwari, 2008). The high concentration of Cr in water is harmful for lungs, liver and hemorrhage organs. The chromium results were observed between 9.2 and 138 µg/L. The Cr of 11 (52.38%) samples were found to be above the permissible limits of WHO (2012) (50 µg/L).

In groundwater and surface water, manganese comes from soils and rocks. Manganese is essential at trace level for proper functioning of both humans and animals but higher intake can damage human nervous system and can cause lack of memory and hallucination. The high concentration of Mn can cause Parkinson infection, bronchitis and lung embolism (Seilkop & Oller, 2003). The manganese results were observed between BD L and 96.9 µg/L. The concentrations of Mn of all samples were found within the permissible limits of WHO (100 µg/L).

The major sources of iron in natural water are mineral from rocks, sediment, oxidized metal, mining and manufacturing waste (Paul Supantha & Mishra Umesh, 2011). The iron results were observed between 10.6 and 133 µg/L. The concentrations of Fe of all samples were within limits (300 µg/L).

Cobalt is found in earth’s crust and natural water. Cobalt has beneficial applications; it is an essential component of vitamin B\textsubscript{12} and beneficial for erythrocytes creation in prevention of anemic situation (Sharma, 1998). Consumption of higher concentration of cobalt can damage liver, kidney, pancreases and heart as well as the skeleton and skeleton muscles (Simonsen et al., 2012). The cobalt results were observed between 12.8 and 49.1 µg/L. The concentrations of Co of all samples were within limits (100 µg/L).

The sources of nickel in water include weathering of rocks, and soils, forest fires, fertilizers, industrial wastes and municipal sewage. Daily intake of Ni through diet is approximately 300 µg. Excess level of nickel in humans is known to cause liver, kidney, brain damage, tissue damage, lung and can also cause cancer of nasal (Babai et al., 2012). The nickel results were observed between BD L to 158 µg/L. The Ni of 11 (52.38%) samples were above the permissible limits of WHO (2012) for drinking (50 µg/L).

Copper is an important source for humans. It is essential for human diet to confirm worthy health in less amount. Nevertheless, at higher concentration it may cause vomiting, diarrhea, liver, nausea and kidney damage (Pawlisz et al., 1992). The copper results were observed between BD L to 92.2 µg/L. The concentrations of Cu of all samples were within limits (100 µg/L).

Cadmium in drinking water is generally a result of the deterioration of galvanized plumbing, industrial waste and use of phosphate fertilizer. Cadmium is an extremely toxic element; the Cd in water can cause nausea, vomiting, digestive issue, sensory disturbances and convulsions. High concentration of cadmium can cause kidney, liver, bone damage, cancer and cardiovascular diseases (McLaughlin et al., 1999). The cadmium results were observed between BD L to 29.4 µg/L. The Cd of 12 (57.14%) samples were higher than permissible limits of WHO (3 µg/L).
| S. NO | Na     | K     | Ca     | Mg     | Cr     | Cd     | Mn     | Fe     | Co     | Ni     | Cu     | Pb     | F     | As     |
|-------|--------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------|--------|
| 1     | 180    | 13    | 140    | 45     | ND     | BDL    | 4.3    | 12.1   | 12.8   | 49.2   | 24     | 7.2    | 3.88  | 0.005  |
| 2     | 190    | 15    | 110    | 38     | ND     | BDL    | 10.6   | 26.1   | 11.9   | 48     | 5.7    | 1.92   | 0.005 |
| 3     | 281    | 12    | 108    | 54     | 34     | 0.8    | BDL    | 8.0    | 21.7   | 26.1   | 32     | 7.4    | 3.82  | 0.01  |
| 4     | 1186   | 117   | 411    | 267    | 9.2    | 28.0   | 7.3    | 22.4   | 36.5   | 14.8   | 30     | 33     | 21.80 | 0.005 |
| 5     | 220    | 12    | 110    | 52     | 10.5   | 4.0    | 20.4   | 110    | 34.6   | BDL    | 14     | 23     | 4.13  | 0.01  |
| 6     | 586    | 20    | 380    | 280    | 50.0   | 12.9   | BDL    | 117    | 49.1   | 35.8   | 13     | 8.7    | 8.57  | 0.005 |
| 7     | 387    | 18    | 420    | 285    | 107    | 15.7   | 16.1   | 119    | 36.6   | 33.8   | 6.7    | 15.7   | 7.76  | 0.00  |
| 8     | 889    | 36    | 590    | 557    | 138    | 7.2    | BDL    | 34.1   | 38.1   | 16.0   | 31     | 30     | 18.30 | 0.00  |
| 9     | 375    | 10    | 350    | 262    | 41     | 1.8    | 8.0    | 25.2   | 41.4   | 15.1   | 25     | 6.2    | 8.14  | 0.005 |
| 10    | 310    | 7     | 175    | 97     | 68     | BDL    | 23     | 106    | 13.3   | 19.0   | 20     | 1.14   | 5.68  | 0.005 |
| 11    | 90     | 10    | 70     | 42     | 107    | 14.8   | 22.9   | 60.4   | 15.8   | 56.9   | 92.1   | 0      | 0.55  | 0.005 |
| 12    | 279    | 26    | 220    | 112    | 39     | 28.2   | ND     | 45.0   | 12.9   | 89.0   | 11.2   | 12     | 5.37  | 0.01  |
| 13    | 338    | 25    | 405    | 228    | 136    | 29.4   | 68.9   | 22.5   | 41.2   | 158    | 5.5    | 28.3   | 11.34 | 0.005 |
| 14    | 177    | 12    | 90     | 47     | 66     | 13.1   | 96.9   | 133    | 260    | 113    | 23     | 0      | 2.70  | 0.005 |
| 15    | 190    | 18    | 233    | 120    | 71     | 12.7   | 43.9   | 85.3   | 293    | 109    | 13     | 0      | 3.74  | 0.005 |
| 16    | 25     | 10    | 30     | 18     | 135    | ND     | 13.0   | 57.7   | 24.7   | 93     | 17     | 0      | 0.39  | 0.01  |
| 17    | 230    | 18    | 110    | 58     | 40     | ND     | 9.3    | 96.7   | 27.3   | 155    | 11.2   | 7.4    | 2.82  | 0.005 |
| 18    | 203    | 24    | 130    | 62     | 87     | 3.7    | 15.1   | 78.7   | 26.5   | 76     | 18.9   | 9.1    | 2.40  | 0.00  |
| 19    | 53     | 11    | 80     | 52     | 132    | ND     | 50.7   | 91.4   | 20.2   | 133    | 19.1   | 0      | 0.78  | 0.005 |
| 20    | 30     | 6     | 27     | 23     | 41     | 2.0    | 17.0   | 101    | ND     | 80.3   | 23.4   | 0      | 0.50  | 0.005 |
| 21    | 320    | 18    | 240    | 105    | 48     | 7.6    | 43.4   | 116    | 27.0   | 120    | 18     | 7.8    | 3.94  | 0.01  |

WHO 200 mg/L 12 mg/L 150 mg/L 50 µg/L 3.0 µg/L 100 µg/L 300 µg/L 100 µg/L 50 µg/L 100 µg/L 10 µg/L 1.5 mg/L 10 µg/L

ND, not detected; BDL, below detection limits.
Automobile fumes consumed have been tested to explain for approximately 50% of overall inorganic lead absorbed by human. The excess level of lead can cause hearing loss, nervous system, aggressive behavior, abdominal cramps and pain, kidney damage, blood pressure and reduced sperm fertilization (Mohan & Hosetti, 1999). The lead results were observed between BDL to 60 µg/L (Table 4). The Pb of six (28.57%) samples were higher than permissible limits of WHO (2012) (10 µg/L) (Figure 4).

Muhammad Balal (Arain. et al., 2008) reported Fe 1.5 to 5.05 mg/L at Manchar lake. The high concentration of iron (Fe) causes a brownish color to clean clothing and also Fe gives harsh taste to water and also less concentration of iron (Fe) causes anemia.

(Salma Bilal, & Sami ur Rahman, 2013 reported the Water quality of Hassan Abdal (Punjab), Pakistan with Cr (11–41 µg/L), Mn (21–51 µg/L), Ni (1–6 µg/L) Cu (1–190 µg/L), respectively. The Cr of 39 samples and Ni of 25 samples were above the WHO limits Cr (50 µg/L) and Ni (50 µg/L), but trace metals were found within the permissible limits of WHO (2010): Mn (100 µg/L), Cu (200 µg/L), Co (100 µg/L) and Fe (300–1000 µg/L). Trace metals are not toxic but its higher concentration in drinking water may be harmful for living organism and cause many diseases).

3.4.1. Arsenic
Arsenic is a very poisonous substance naturally found in rocks, soil and water. Many aquifers comprise higher concentration of arsenic containing salts so that arsenic makes water contaminated. The WHO guideline for arsenic is 0.01 mg/L for drinking water. The short term of arsenic exposure to high level of (As) in drinking may cause diarrhea, stomach, vomiting, muscular, weakness, skin rash, pain in feet and also hands, loss of movements. The large period exposure to higher concentration of (As) in drinking water may also cause discoloring of membrane, nausea, diarrhea, reduced creation of blood cells, heart regularity, and damage blood vessel. High level of (As) in
drinking water may growth the threat of cancer in tissues like liver, bladder and lungs (Wadhwa, 2011). The arsenic results were observed between BDL to 0.010 mg/L. The arsenic of all samples were within the permissible limits of WHO (2012) (10 µg/L).

3.4.2. Fluoride
Fluoride (F) is a natural element that is found in soil and groundwater. The chief source of fluoride in groundwater is fluoride-bearing rocks like cryolite, fluorspar, hydroxyapatite, fluorite and fluorapatite (Meenakshi et al., 2004). Low level of fluoride is beneficial for human and it protects tooth enamel against the acids that cause tooth decay. The high content of fluoride in water may cause weaken bones, muscles and nervous problems. The fluoride results were observed between 0.39 and 21.80 mg/L. The fluoride 4 samples were within the permissible limits of WHO for drinking purpose (1.5 mg/L), 3 samples within the permissible limits for drinking purpose (3.0 mg/L) (Figure 5). 14 samples were above the permissible limits for drinking purpose (> 3 mg/L) (Table 4). It is observed that the fluoride varied with variation of TDS, the fluoride increased with the values of TDS increased. Tahir and Rasheed (2013) reported that only 16% samples out of 747 were found to be dangerous, whereas the 84 % samples were found to be safe. The 747 samples were collected from tube wells, hand pumps, wells, bores and water supply schemes of 16 cities of the Pakistan.

3.4.3. Scatter diagram analysis
The Scatter diagram draws the plot fluoride versus TDS with the help of (Microsoft excel 2013). A scatter diagram is used to know the relationship between two variables Y- and X-axes. If variables are correlated to each other, the curve will be
linear; the diagram Y-axis represented the fluoride concentration and X-axis represented the TDS value. The scatter diagram indicated the correlation of parameters in each others. The first cluster of dots gathered between TDS 1000 and 2000 mg/L, and second cluster of dots gathered between TDS 2000 and 3000 mg/L. It is observed that the concentration of fluoride increased with the value of TDS increased (Figure 6).

### 3.4.4. Correlation determination

Correlation is used to determine the degree of closeness between the dissimilar variables (Nesrine et al., 2015). Table 5 shows the correlation of parameters of taluka Qamber to each other. The EC is good correlated with TDS, total hardness, sulfate, calcium, magnesium (>0.7), moderate correlated to potassium and fluoride (0.5–0.7) but less correlated to pH and phosphate (<0.5). The pH was negative correlated to all parameters. Alkalinity is moderate correlated to SO$_4^{2-}$ and Ca$^{2+}$ but less correlated to other parameters. Potassium is less correlated to calcium and magnesium. Chloride is less correlated to alkalinity and total phosphate–phosphorous (<0.5). The correlation showed that the major parameters were good correlated to each other which indicated that these samples were within similar geological locations.

### 3.4.5. Hierarchical cluster analysis

The cluster analysis is a process that enables the combination of related locations on the basis of distance conditions and specific aggregative procedure in direction to create a topology which describes the similarities between the classes and dissimilarities between the different classes. The value of cluster supports the understanding the data and pattern (Sneath & Sokal, 1973). The cluster analysis is designed consecutively by opening with the related pair of objects and creating higher groups step by step going to the bottom. The hierarchical clusters are completed on the normalized data set.
(average value) by using wards method (Sneath & Sokal, 1973).

The cluster analysis method was used for the 21 groundwater samples of taluka Qamber to known the similarity among sampling locations (Figure 7). The samples were observed to be grouped into three clusters in dendrogram. Group A is divided into A1 and A2, group A1 is based on 11 samples with sample numbers 16, 20, 11, 19, 5, 17, 1, 18, 2, 14, 3 and A2 contain 4 samples with numbers 10, 21, 12 and 15. The cluster B contains 4 samples 7, 9, 6, and 13. The cluster C contains 2 samples 4 and 8. It is observed that group C samples have higher values for most of parameters than group A and B. Similarly, the group B has higher values in terms of average concentration then group A.

3.4.6. Hydrochemical composition

The piper diagram drawn with the help of Aquachem software and is used to describe the hydrochemical compositional structures in two similar triangles along with diamond to top of the (Figure 8) (Vikas Tomar et al., 2012). The anions grouped HCO$_3^-$, SO$_4^{2-}$ and Cl$^-$ are indicated in triangle right and cations grouped Na$^+$, K$^+$, Ca$^{2+}$, Mg$^{2+}$ in triangle left and diamond to top of the figure established in a trilinear diagram indicates the Ca$^{2+}$, Mg$^{2+}$ and Cl$^-$, SO$_4^{2-}$ and the nature of groundwater. The triangle right showed predominance of Cl$^-$ toward HCO$_3^-$ and SO$_4^{2-}$ and triangle left showed predominance of Na$^+$ and K$^+$ toward Ca$^{2+}$ and Mg$^{2+}$. 

Figure 7. Dendrogram of anions and cations of study area.

Figure 8. Piper diagram of anions and cations of study area.
The 21 groundwater samples were applied for the diagram. The right side of triangle indicated approximately all groundwater samples were rich in chloride, and indicated chloride type water within 60–100%. The left side of triangle indicated slightly sodium type water. The Ca$^{2+}$, Mg$^{2+}$ and Cl$^{-}$, SO$_4^{2-}$ were found at both sides simultaneously and arrows raised upward within diamond shape of diagram. The most of samples gathered upward Ca$^{2+}$ and Cl$^{-}$ and also indicated that the water samples were calcium and chloride type also.

### 3.4.7. Principal component analysis

Principal components analysis (PCA) was carried out with SPSS 22 Software. It is a powerful tool that attempts to describe the variance of the large dataset of inter correlated variables with the smaller dataset of independent variables (Simeonov et al., 2003). PCA extracts an eigenvalues from covariance matrix of original variables and weighted linear combination of original variables. The rotated components matrix for 25 physicochemical parameters for the water samples of taluka Qamber are shown in (Table 6). It includes loading components for rotated matrix, percent and cumulative percent of variance described by each component. It shows that the rotated principal components account together for 70.103% of the total variance of the dataset. In which the first component is 43.019%, second component 15.996% and third component 11.088% of total variance. The eigenvalues of three components are greater than 1, and can be used to evaluate the leading of hydrogeochemical process.

The component 1 which is based on load 43.019% indicated for parameters conductivity, TDS, chloride, sulfate, total hardness, sodium, calcium, magnesium, and cobalt with high positive loading (0.767–0.961), potassium, chromium and cadmium medium positive loading (0.512–0.583) and alkalinity, fluoride, NO$_3$, NO$_2$, Ni, Mn and Pb low positive loading (0.132–0.468). Similarly the component 2 Which has 15.996% indicated high loading only for nickel (0.956), moderate positive loading for Cd and Mn (0.506–0.576) and low positive loading for conductivity, TDS, calcium, total hardness, sulfate, potassium, fluoride and alkalinity (0.152–0.473). The component 3 which has loading of 11.088% has moderate positive loading for alkalinity, As (0.647–0.696) and low positive loading for pH conductivity, TDS, Ca, Na, SO$_4$, total hardness, K, Cd, F and O PO$_4$ (0.121–0.480). It reflects the composition of the components within the water bodies at taluka Qamber.

### 3.5. Suitability of Water for irrigation

#### 3.5.1. Salinity Hazards

The salinity hazards calculated on the basis of EC, According to results only two samples were in low and medium salinity categories EC less than 500 and 500 to 1000 uS/cm respectively, 7 samples in high EC 1000-3000 and 10 samples were in very high EC above than 3000 uS/cm salinity categories respectively (Figure 9).

#### 3.5.2. Sodium percentage (Na%)

For calculation of sodium percentage of water samples, Doneen method was used. The Na % was determined as follows:

$$\text{Na\%} = \left( \frac{(\text{Na}^+ + \text{K}^+)/\text{(Ca}^{2+} + \text{Mg}^{2+} + \text{Na}^+ + \text{K}^+)} \right) \times 100$$

The concentrations of sodium percentage were expressed in meq/L. Sodium percentage results of natural water are divided into three categories: (good) 20–40 Na%, (permissible) 40–60 Na%, and (doubtful) 60–80 Na% (Doneen, 1964). The Na% were found between 23.6 and 55.8 Na %; 11 (52.38%) samples were in good (20–40 Na %), 10 (47.62%) samples were permissible (40–60 Na %) and no sample was in doubtful (60–80 Na %) categories.

#### 3.5.3. Sodium absorption ratio (SAR)

SAR value is used to calculate the quality of water for crops and irrigation and to determine the alkali/Na threat to crops. The alkali/hazard is usually indicated
as SAR. This index calculates the ratio of Na\(^+\) to Ca\(^{2+}\) and Mg\(^{2+}\) ions in the water sample (Masood Alam et al., 2012):

\[
SAR = \frac{Na}{\sqrt{Ca + Mg}}
\]

All ions were shown in meq/L. The SAR also affects infiltration rate of natural water. Therefore, low SAR is essential. If SAR value is less than 6 the sample is suitable for irrigation and if SAR value is greater than 6 the sample is not suitable for irrigation.

The SAR values were between 0.81 and 10.94 meq/L. A total of 19 analyzed groundwater samples were within permissible limits for irrigation and two samples were above the permissible limits.

3.5.4. Kelly’s index (KI)
Kelly’s index (KI) is used for arrangement of groundwater for crops and irrigation. The Na\(^+\) determined against (Ca\(^{2+}\)) and (Mg\(^{2+}\)) is used to calculate the KI for irrigation. The KI (>1) shows a higher concentration of Na\(^+\) in the water (Kelly, 1940). Consequently, water with a KI (<1) is good for crops and the water with higher Na ratio is not suitable for crops and irrigation (Sundaray, Nayak, & Bhatta, 2009). The value of KI is expressed in meq/L as follows:

\[
KI = \frac{Na}{Ca^{2+} + Mg^{2+}}
\]

KI in the study area were found between 0.28 and 1.23 meq/L. It was observed from the study that 85.71% samples were suitable for agriculture and 14.28% samples were unsuitable for irrigation.

3.5.5. Permeability index (PI)
The permeability index (PI) of water and soil is threatening by continuous use for irrigation. Groundwater is affected by Na\(^+\), Ca\(^{2+}\), Mg\(^{2+}\) and HCO\(_3^-\) substances in water and soil. The measure for considering the permeability of water for crops is based on PI (Bashir et al., Huda, Naseem, Hamza, & Kaleem, 2015). The PI is determined as follows:

\[
PI = \left(\frac{(Na^+ + HCO_3^-)/(Ca^{2+} + Mg^{2+} + Na^+)}{2}\right) \times 100
\]

The PI in the study area were found between 36.4 and 100 meq/L. It was observed from the study that 38.1% samples were in high permmissibility PI (75%) Class I which was good for irrigation and 42.86% samples were between 50% to 75% (Class II), which
was suitable for irrigation uses and 19.04% samples were in less than 50% permissibility (Class III) which was unsuitable for irrigation uses.

### 3.5.6. Chloro alkaline indices (CAI-1)

It is necessary to identify the chemical arrangement of natural water changes when it is passing through subsurface, the ion conversation among the water and its environment through residence can be known by learning the CAI-1 (Schoeller, 1977). The CAI-1 is determined as follows:

\[
\text{(CAI-1)} = \frac{\text{[Cl}^- -(\text{Na}^+ + \text{K}^+)]/\text{Cl}^-}
\]

If CAI-1 is negative, it means there is base exchange among (Na\(^+\) and K\(^+\)) in the water with (Ca\(^{2+}\) and Mg\(^{2+}\)) in soils and rocks. If CAI-1 ratio is positive, it means there cannot be base exchange.

The chloro alkaline indices 1 indicates that 47.38% of the water were negative ratios and 52.38% water samples were positive ratios.

### 3.5.7. Chloride sulfate ratio

Chloride sulfate ratio is used to calculate the suitability of water for irrigation and agriculture. If chloride sulfate ratio is greater than 1, the water sample is salty (Al-Harbi, 2009). All ions were shown in meq/L.

Chloride sulfate ratio is calculated as follows:

\[
\text{Chloride sulfate} = \text{Cl}^-/\text{SO}_4^{2-}
\]

The chloride sulfates in the study area were found between 0.50 and 7.61 meq/L. The 76.19% samples chloride sulfate ratio was greater than 1 and 23.81% samples were less than 1.

### 3.5.8. Residual sodium carbonate (RSC)

The residual sodium carbonate (RSC) is used to measure the harmful influence of carbonate (CO\(_3\)\(^{2-}\)) and bicarbonate (HCO\(_3\)\(^{-}\)) on the suitability of water for agriculture purposes (Janardhana Raju, 2007). The value of RSC is calculated as follows:

\[
\text{RSC} = \left(\frac{\text{Cl}^- + \text{CO}_3^{2-}}{\text{Ca}^{2+} + \text{Mg}^{2+}}\right)
\]

The RSC is divided into three categories for irrigation: “safe” (< 1.25), “marginal” (1.25–2.5) and “unsuitable” (>2.5). The RSC values of all samples were found to be in “safe” category (<1.25 meq/L), negative, so that water of study area was suitable for irrigation and crops.

### 3.5.9. Chloride bicarbonate ratio

Chloride bicarbonate ratio is used to calculate the suitability of water for irrigation and agriculture. If chloride bicarbonate ratio is greater than 1, the water sample is salty (Al-Harbi, 2009). All ions were shown in meq/L.

Chloride bicarbonate is calculated as follows:

\[
\text{Chloride bicarbonate} = \frac{\text{Cl}^-/\text{HCO}_3^-}
\]

The chloride bicarbonates in the study area were found to be between 0.26 and 17.00 meq/L. The 76.19% samples chloride bicarbonate ratio was greater than 1 and 23.81% samples were less than 1.

The overall results indicate that 75–90% samples are suitable for irrigation. It is therefore suggested that the water may be used for irrigation with care, keeping in view of the quality of water (Table 7).

### 4. Conclusion

The present study analyzed the groundwater of taluka Qamber of District Qamber Shahdadkot. The samples analyzed were compared with standard values of WHO for drinking water. The pH values of all samples of talukas Qamber were found within the permissible limits. The results of EC and total dissolved solids of 81% were found above the WHO limits. The
concentration of anions and cations of Qamber about half of samples were found above the limits. The fluoride 19.05% samples were suitable for drinking, 14.28% samples within maximum permissible limits for drinking and 66.66% samples were above the maximum permissible limits for drinking.

The heavy metals like Fe, Mn, Co and Cu of all samples were within permissible limits of WHO but concentration of Cr and Ni 52.38%, Cd 57.14%, and Pb 28.57% samples were higher than permissible limits of WHO. The high concentration of chromium is due to the industrial, drainage and agriculture wastage in the study area. The heavy metals were decreasing order Fe>Ni>Cr>Co>Mn> Cu>Cd>Pb.

The concentrations of NO₂⁻ -N, T -PO₄³⁻ -P and O -PO₄³⁻ -P, COD and arsenic were within permissible limits of WHO. The concentration of chloride 76.1%, nitrate-N 9.52%, hardness 43%, alkalinity and K⁺ 57.1%, Na⁺ and SO₄²⁻ 62%, Ca and Mg 47.6% were higher than permissible limits of WHO. The water quality of taluka Qamber at majority of places is not suitable for human consumption.

The Na%, SAR, KI, PI, RCS, CAI-1, chloride bicarbonate ratio, chloride sulfate ratio to know the suitability of water for irrigation. According to current work, 40–90% of water samples of study area were suitable for irrigation purposes.

Maltivarient analysis techniques, cluster analysis, principal component analysis and piper diagram were used to calculate the similarity among the sampling stations, the variation among the large dataset and hydrochemical composition of the anions and cations respectively.

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Disclosure statement

No potential conflict of interest was reported by the authors.

References

Abbulu., R. (2013). A study on physico-chemical characteristics of groundwater in the industrial zone of Visakhapatnam, Andhra Pradesh. American Journal of Engineering Research, 2(10), 112–116.

Agarwal, B. R., Mundhe, V., Hussain, S., & Pradhan, V. (2012). Assessment of bore well water quality in and around Badnapur Dist. Jalna. Journal of Chemical and Pharmaceutical Research, 4, 4025–4027.

Al-Harbi, O. A., Hussain, G., & Lafouza, O. (2009). Irrigation water quality evaluation of Al-Mendash groundwater and drainage water, Al-Madenah Al-Monawarah region, Saudi Arabia. International of Soil Science, 4, 123–141.

American Public Health Association. (1992). WPCF, Standard methods for the examination of water and wastewater. American Public Health Association/American Water Works Association/Water Environment Federation (18th ed). Washington, DC.

American Public Health Association. (1995). WPCF, Standard methods for the examination of water and wastewater. Washington DC, USA: American Public Health Association/American Water Works Association/Water Environment Federation.

American Public Health Association, American Water Works Association, Water Pollution Control Federation, & Water Environment Federation. (1913). Standard methods for the examination of water and wastewater. Washington, DC: American Public Health Association.

Anurag, T., Ashutosh, D., & Aviral, T. (2010). A study on physico-chemical characteristics of groundwater quality. Journal ChemicalPharmacologyResearch, 2(4), 510–518.

Arain., M. B., Kaz., T. G., Jamali., M. K., Afridi., I. H., Baig., J. A., Nusrat, J., & Shah., A. Q. (2008). Evaluation of physico-chemical parameters of Manchar lake water and their comparison with other global published values,” Pak. Journal of Anl Environmental Chemistry, 9(2), 101–109.

Babai, K. S., Poongothai, S., Lakshmi, K. S., Punniyakotti, J., & Meenakshisundaram, V. (2012). Estimation of indoor radon levels and absorbed dose rates in air for Chennai city, Tamilnadu, India. Journal of Radioanalytical and Nuclear Chemistry, 293(2), 649–654.

Bashir, E., Huda, S. N., Naseem, S., Hamza, S., & Kaleem, M. (2015). Geochemistry and quality parameters of dug and tube well water of Khipro, district Sanghar, Sindh, Pakistan. Applied Water Science, 7(4), 1645–1655.

Chandio, N. H., & Anwar, M. (2009). Impacts of climate on Agriculture and it’s causes: A Case study of Taluka Kamber, Sindh, Pakistan. Sindh University Research Journal (Science Series), 4(12), 59–64.

Dixit, S. & Tiwari, S. (2008). Impact assessment of heavy metal pollution of Shahpura Lake, Bhopal, India. International Journal of Environmental Research, 2(1), 37–42.

Dobrzański, B., & Zawadzki, S. (1981). Pedology (pp. 613). Warszawa: PWR.

Doneen, L. D. (1964). Notes on water quality in Agriculture, Paper 4001 ed. Department of Water Sciences and Engineering, University of California: Published as a Water Science and Engineering.

Gale, R. P., Champlin, R. E., Feig, S. A., & Fitchen, J. H. (1981). Aplastic anaemia biology and treatment. Annals of Internal Medicine, 95(4), 477–494.

Jahangir, T. M., Khuhawar, M. Y., Leghari, S. M., Mahar, M. T., & Khaskhel, A. A. (2013). Chemical assessment of natural springs of Sindh Pakistan. Canadian Journal of Pure and Applied Sciences Senra Academic Publishers, British Columbia, 7(2), 2431–2449.

Jain, C. K., Kumar, C. P., & Sharma, M. K. (2003). Groundwater qualities of Ghatarpraba command area Karnataka. Indian Journal Environ and Ecoplan, 7(2), 251–262.

Jameel, A. (2002). Evaluation of drinking water quality in Tiruchirapalli, Tamil Nadu. Indian Journal of Environmental Health, 44(2), 108–112.

Jayalakshmi, V., Lakshmi, N., & Singara Charya, M. A. (2011). Assessment of physico-chemical parameters of water and waste waters in and around Vijayawada.
International Journal of Research in Pharmaceutical and Biomedical Sciences, 2(3), 1040–1046.

Kandhrè, A. J., Bind, A. M., Mastoi, A. A., Almani, K. F., Meghwar, S., Laghari, M. A., & Raipout, M. S. (2015). Physico-chemical assessment of surface and ground water for drinking purpose in Nawabshah city, Sindh, Pakistan. American Journal of Environmental Protection, 41, 62–69.

Karanth, K. R. (1987). Groundwater assessment, development and management (p. 455). New Delhi: Mcgraw Hill Publishing Company Limited.

Kelly, W. P., (1940). Permissible composition and concentration of irrigated waters. Proceeding of the ASCF, 66, 607.

Khan, A. R., Haq, I. U., Khan, W. A., Akif, M., Khan, M., & Riaz, M. (2000). Quality characteristics of potable water of Mardan city (Pakistan) and surrounding areas. Journal-Chemical Society of Pakistan, 22(2), 87–93.

Khan, A. R., Marwat, G. A., & Riaz, M. (2005). Potable water quality characteristics of the urban areas of Peshawar (Pakistan) part 2: Well water. Journal of the Chemical Society of Pakistan, 27(3), 239–245.

Lodi—li, Z. H., Akif, M., & Kalsoom, U. (2003). Evaluation of drinking water from different sources in Skardu-Northern area with special reference to heavy metals. Journal of Chemical Society Pakistan, 25, 2.

Mahmood., K., Alamgir., A., Khan., M. A., Shaukat., S. S., Lodi Khan, A. R., Marwat, G. A., & Riaz, M. (2007). Canadian water quality guidelines for chromium. Environmental Toxicology and Water Quality: Environmental Toxicolog, 12(2), 123–183.

Raju, J. (2007). Hydrogeochemical parameters for assessment of groundwater quality in the upper Gunjanaeru River basin, Cuddapah District, Andhra Pradesh, South India. Environmental Geology, 52, 1067–1074.

Raveneau, R., & Burrough, P. A. (1988). Principles of geographical information systems for land resources assessment 192. Oxford: Oxford university press. Cahiers de géographie du Québec, vol. 32, no. 85, p. 76.

Sajil Kumar, P. J., & James, E. J. (2013). Physicochemical parameters and their sources in groundwater in the Thirupathur region, Tamil Nadu, south India. Applied Water Science, 3(1), 219–228.

Salma, B., & Ur Rahman, S. (2013). Determination of trace elements in the drinking water of Hassan Abdal, Punjab, Pakistan. Journal of Scientific and Innovative Research, 2, 02.

Samina, J., Jaffar, M., & Shah, M. H. (2004). Physico-chemical profiling of ground water along Hazara strip, Pakistan. Journal of the Chemical Society of Pakistan, 26(3), 288–292.

Satish Kumar, K. (2015). Water availability assessment in Shipra river. International Journal of Research in Engineering and Technology, 04(11), 126–130. Nov. 2015.

Schoeller, H. (1977). Geochemistry of groundwater. In Ground water studies-An international guide for research and practice (Ch. 15, pp. 1–18). Paris: UNESCO.

Seilkop, S. K., & Oller, A. R. (2003). Respiratory cancer risks associated with low-level nickel exposure: An integrated assessment based on animal, epidemiological, and mechanistic data. Regulatory Toxicology and Pharmacology, 37(2), 173–190.

Sharma, Y. R. (1998). Elementary organic spectroscopy. New Delhi: S. Chand and Company.

Shehzadi, R., Rafique, H. M., Abbas, I., Sohl, M. A., Ramay, S. M., & Mahmood, A. (2014). Assessment of drinking water quality of Tehsil Alipur, Pakistan. Desalination and Water Treatment, 55(8), 2253–2264.

Simeonov, V., Stratis, J. A., Samara, C., Zachariadis, G., Voutsas, D., & Anthemidis, A. (2003). Assessment of the surface water quality in Northern Greece. Water Research, 37, 4119–4124.

Simonsen, L. O., Harbak, H., & Bennekou, P. (2012). Cobalt metabolism and toxicology-A brief update. The Science of the Total Environment, 432, 210–215.

Sittig, A. C., Van der Gon, J. J. D., & Gielen, C. C. A. M. (1985). Separate control of arm position and velocity demonstrated by vibration of muscle tendon in man. Experimental Brain Research, 60(3), 445–453. Nov.

Sneth, P. H., & Sokal, R. R. (1973). Numerical taxonomy the principles and practice of numerical classification (pp. 573). San Francisco: W. H. Freeman.

Strazzullo, P., D’Elia, L., Kandala, N., & Cappuccio, F. P. (2009). Salt intake, stroke, and cardiovascular disease: Meta-analysis of prospective studies. BMJ, 339(nov24 1), b4567–b4567. Nov.

Sundar, M. L., & Saseetharan, M. K. (2008). Groundwater quality in Coimbatore, Tamil Nadu along Noryal River. Journal of Environmental Science & Engineering, 50(3), 187–190.

Sundaray, S. K., Nayak, B. B., & Bhatta, D. (2009). Environmental studies on river water quality with reference to suitability for agricultural purposes: Mahanadi river estuarine system, India–A case study.
Supantha., P., & Umesh., M. (2011). Assessment of underground water quality in North Eastern region of India: A case study of Agartala City. *International Journal of Environmental Sciences*, 2(2), 850–862.

Tahir, M. A., & Rasheed, H. (2013). Fluoride in the drinking water of Pakistan and the possible risk of crippling fluorosis. *Drinking Water Engineering and Science*, 6(1), 17–23.

Tariq, S. R., Shah, M. H., Shaheen, N., Jaffer, M., & Khalique, A. (2008). Statistical source identification of metals in groundwater exposed to industrial contamination. *Environmental Monitoring and Assessment*, 138(1–3), 159–165. Hazara strip, 2004.

Tomar, V., Kumar, A., & Khajuria, V. (2012). Hydro-chemical analysis and evaluation of groundwater quality for irrigation in Karnal district of Haryana state, India. *International Journal of Environmental Sciences*, 3(2), 756.

Trivedy, R. K., & Goel, P. K. (1984). *Chemical and biological methods for water pollution studies* (pp. 1–211). Karad: Environmental Publications.

Ur-Rahman, A., & Khan, A. R. (2000). Potable water quality characteristics of the urban areas of Peshawar (Pakistan) part 1: Tubewell water. *Journal of the Chemical Society of Pakistan*, 22(3), 171–177.

Wadhwa, S. K., Kazi, T. G., Chando, A. A., Afridi, H. I., Kolachi, N. F., Khan, S., … Baig, J. A. (2011). Comparative study of liver cancer patients in arsenic exposed and non-exposed areas of Pakistan. *Biological Trace Element Research*, 144(1–3), 86–96.

Wara Rao, V. (2011). Physicochemical analysis of selected ground water samples of Vijayawada rural and urban in Krishna district, Andhra Pradesh, India. *International Journal of Environmental Sciences*, 2, 710–714.

WHO. (2012). *Progress on drinking water and sanitation*. Geneva, Switzerland: World Health Organization.