

## Water Quality Assessment and Hydrochemistry of Shallow Groundwater in Bhara Kahu area, Islamabad, Pakistan

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**Abstract:** The groundwater quality of Bhara Kahu, Islamabad has been evaluated using water samples collected from 8 localities. The analysis has been performed to determine the drinking and irrigation groundwater quality. The standard procedures were adopted after the American Public Health Association (APHA) for sampling. The analysis revealed the concentration of the Ca, K, Mg, Na, NO<sub>3</sub>, HCO<sub>3</sub>, SO<sub>4</sub>, Cl, Total Dissolved Solids (TDS), hardness, turbidity, pH, alkalinity and Electrical Conductivity (EC). The World Health Organization (WHO) standards were used to compare with the results for the determination of the quality of groundwater. It is concluded that the groundwater in the Bhara Kahu area is not polluted and may be used for drinking purpose. The geochemical evolution of groundwater describes it to be of Ca-HCO<sub>3</sub> type showing a single aquifer having a younger groundwater. The suitability of the groundwater determined by the EC and the sodium hazard determines the groundwater to be safe.

**Keywords:** Groundwater, physicochemical, Bhara Kahu, hydrochemical facies.

### Introduction

Water is a requirement that sustains life and without it life will be impossible (Fetter, 1980). The groundwater is rapidly gaining its importance in areas showing shortage of surface water (Uma and Egboka, 1985; Foster et al., 1999; Sundary et al., 2006). Pakistan is one of the semi-arid countries with scarce water resources with high stress that will ultimately lead to severity in the future (Hamazah et al., 1997). According to USGS (2005), groundwater is one percent of the Earth's water and it is 100 times of the total volume of water in lakes and rivers in the world. As a result there is per capita shortage of groundwater availability from 5600 to 1000 m<sup>3</sup>/annum (Hamazah et al., 1997). Moreover, in the last ten years excessive usage of water resources in particular groundwater has been recorded due to increased population, continual industrial development and urbanization (Khahlow et al., 2002) and out of these the increased pollution is one of the main threat to water resources (Ahmed and Ali, 2000). Additionally compared to 90's, a 200 percent increase in the patients has been found due to the anthropogenic effects on the groundwater in Pakistan (Tahir and Bhatti, 1994).

Bhara Kahu lies in the outskirts of Islamabad and has seen an enormous growth in population and economic activity due to its location within a decade. It is the need of the time to have a preliminary investigation about the natural resources availability and quality. The present study was undertaken to investigate the groundwater quality at different locations of Bhara Kahu. Thus, in this research work an attempt has been made to assess the physicochemical parameters of

groundwater that are affecting the quality of groundwater for drinking and irrigation purposes.

### Study area

The study was conducted in the Bhara Kahu area of Islamabad. Bara Kahu is located at 33° 44' 24" N latitude and 73° 10' 47" E longitudes, at the edge of Potwar Plateau south of the Margalla hills. Islamabad lies in the south of Bhara Kahu with the distance of 5-10 km and is easily accessible. The hot and humid weather is observed in summer and sufficient rainfall in monsoon season from July to September followed by mild and wet winter (Sheikh et al., 2008). Mainly Rawal and Simly dams have been built on Kurang and Soan streams respectively draining this area. Water from these dams is supplied to Islamabad and Rawalpindi area. The water table depth varies between 100 and 2 m from Margalla Hills to the Soan River where water table depth lies between 2 to 20 m (Ashraf and Hanif, 1980). Groundwater is utilized for various purposes in this area such as household, industry and agriculture.

Sedimentary rocks exposed in Islamabad area record 150 m.y. of geologic history from the Middle Jurassic to the Quaternary (Sheikh et al. 2008). The oldest rocks exposed in the study area are Jurassic marine limestone and dolomite of the Samana Suk Formation followed by the glauconitic shale and sandstone of the Chichali Formation. The Chichali Formation was overlain by the glauconitic sandstone of the Lumshiwai Formation. In early Late Cretaceous, marls of the Kawagarh Formation were deposited over Lumshiwai Formation which was then followed unconformably by highly weathered continental sediments of the Hangu

Formation. Calcareous and argillaceous sediments of the Lockhart Limestone, Patala Formation, Margala Hill Limestone, and Chorgali Formation were deposited during the Eocene time. This marine depositional sequence was followed by alternate marine and continental environments during which the Kuldana Formation was deposited that produced the unconformity beneath the continental Murree Formation. Following the Kuldana Formation Miocene and Pliocene, very thick continental deposits of the Rawalpindi and Siwalik Groups accumulated in the subsiding Himalayan foredeep region. During the Pliocene, sedimentation was controlled by an eastward-flowing river system. Local sedimentation stopped between 3 Ma and 1 Ma, when the sandstone and mudstone of the Rawalpindi and Siwalik Groups were folded and faulted throughout the area (Sheikh et al., 2008). The current study area shows the Murree Formation and the pockets of Quaternary alluvium (Khan, 1987). The nature of the aquifers range from confined to semiconfined mostly in the gravels of the Quaternary alluvium or in the sands of the Murree Formation. Mostly, on southern and western aspects of the Potwar Plateau, the soil is thin and infertile. Limestone is the characteristics of Margalla Range. It is gray and bluish white and the soil formed by the disintegration of shells, clay and sandstone.

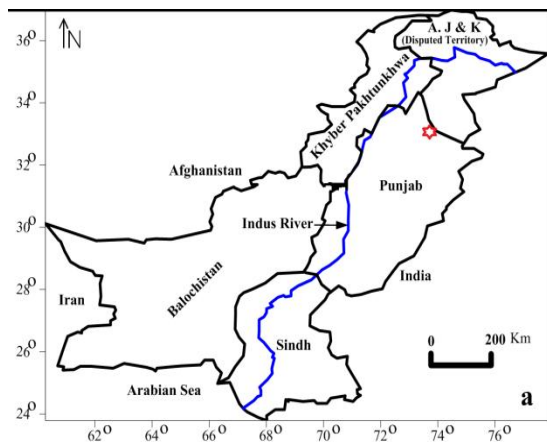


Fig. 1 a Location map of Bhara Kahu, marked by red star.

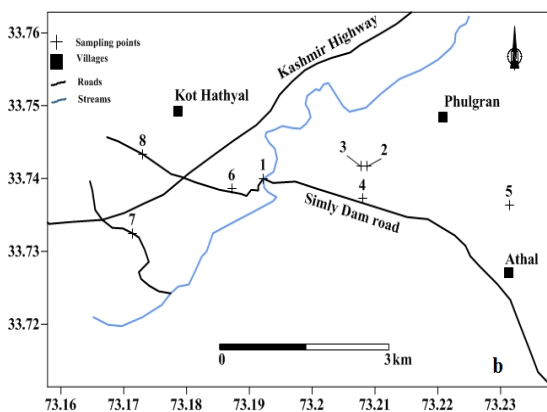


Fig. 1 b Shows the sampling points.

## Materials and Methods

Groundwater sampling has been carried out in eight different locations in Bhara Kahu using GPS to mark the exact location of the wells. The samples were collected over a period of four months (April to July 2011). Sampling sites have been selected on the basis of groundwater flow and recharge of groundwater on the basis of the concept of Toth (1970) i.e. usually the depressions are the natural discharge areas whereas the highs are the recharge areas. All samples were clearly labeled by site, number of sample and status. Well capped Polyethylene Van Dorn plastic bottles were used to store samples. An ice box was used to keep the samples' temperature at 4 °C. All samples were analyzed for temperature, pH, Electrical Conductivity (EC), Turbidity, Alkalinity, Hardness, Total Dissolved Solids (TDS), Bicarbonates ( $\text{HCO}_3$ ), Carbonates ( $\text{CO}_3$ ), Nitrate ( $\text{NO}_3$ ), Sulfate ( $\text{SO}_4$ ), Sodium (Na), Potassium (K), Calcium (Ca), and Magnesium (Mg) using standard methods of Pakistan Council of Research in Water Resources (PCRWR).

Temperature, pH, EC and TDS were calculated by thermometer, pH meter (781-pH meter, Metrohm) and conductivity meter respectively in laboratory. Total Alkalinity was determined by acid titration (Methyl-Orange - indicator), whereas Total Hardness, as Ca hardness, was measured by EDTA complexometry titration (Erichrome-black-T and Calcon-indicators). Turbidity was analyzed by Nephelometric method (Formazin polymer- reference turbidity standard suspension).

Calcium was examined through EDTA titration method using sodium hydroxide, Murexide indicator and Standard EDTA titrant as reagents. Molybdo-vanadate method was used for the determination of phosphate while nitrate analysis was done on UV-VIS Spectrophotometer (Analytik Jena).

Chloride was analyzed by titration method involving Standard silver nitrate solution reagent and Potassium Chromate indicator. Sulfate was analyzed by UV-VIS spectrometer and magnesium was determined by using the difference between hardness and calcium as  $\text{CaCO}_3$ .

## Results and Discussion

The physicochemical parameters exhibited considerable variations from sample to sample. The average results of the physicochemical parameters of samples are presented in Table 1 along with the limits defined by the World Health Organization (WHO).

The analysis revealed that the electrical conductivity is higher in all samples except for 8. The nature of water that is alkaline or acidic, is determined by the help of pH. However the permissible limits of the pH set by WHO lies between 7.0–8.5 and all the samples are well within the limits and show neutral to acidic character

(Table 1). Acidic waters contain high contents of sulphate and less or no content of bicarbonate (Azeez et al., 2000). However, in case of the waters analyzed both are playing a crucial role as depicted in Table 1. Moreover, acidic waters also contain high concentrations of chloride, magnesium, calcium and sodium relative to other samples. Whereas in these samples, all the analysis results are below permissible limits except calcium that shows highest values as compared to the rest of the parameters and in some samples cross the permissible limit as seen in Figure 2 and Table 1. The high concentrations of calcium ions are indicative of the impact of the geology of the area that mostly contains the Murree Formation and limestones that has the calcitic cements. Moreover, the surrounding rocks at the high elevated recharge areas contain mostly limestones from different formations and slightly

lower in these groundwaters. The TDS values are higher in localities 2 to 4 and 7. The acceptable limit defined by the WHO is 500 mg/l.

The cations analyzed included Ca, Mg, K and Na and the permissible limits defined by the WHO are 100, 150, 12 and 200 mg/l respectively. All samples except 1 and 8, values of the calcium in samples are above the permissible limit. The values of Mg, K and Na lie well within the range as defined by WHO. The SO<sub>4</sub>, NO<sub>3</sub>, HCO<sub>3</sub> and Cl<sup>-</sup> have been defined to have the permissible limits of 250, 50, 500 and 250 mg/l respectively. All the samples anionic concentrations lie well below the permissible limits except sample 5.

The physicochemical parameters correlation matrix in groundwater is given in Table 2. In groundwater the

Table 1 The general characteristics of the study area and its groundwater. The “NGV” stands for No Guideline Value.

| Sample No.                      | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    | WHO |
|---------------------------------|------|------|------|------|------|------|------|------|-----|
| Elevation (m)                   | 1871 | 3608 | 2009 | 2001 | 1905 | 1912 | 1900 | 1956 |     |
| Depth to Water (m)              | 30   | 30   | 25   | 40   | 45   | 42   | 40   | 50   |     |
| Electrical Conductivity (µS/cm) | 837  | 1091 | 1117 | 999  | 822  | 806  | 929  | 345  | 600 |
| pH                              | 7.1  | 6.87 | 6.94 | 7.08 | 6.84 | 6.75 | 7.15 | 7.59 | 8.5 |
| Turbidity (ntu)                 | 0.83 | 1.92 | 0.67 | 0.6  | 1.18 | 0.69 | 5.37 | 3.31 | NGV |
| Temperature (oC)                | 28   | 28   | 28   | 28   | 28   | 28   | 28   | 28   |     |
| TDS (mg/l)                      | 460  | 655  | 670  | 599  | 493  | 484  | 557  | 190  | 500 |
| Alkalinity (mg/l)               | 282  | 392  | 392  | 432  | 412  | 272  | 347  | 152  | NGV |
| Hardness (mg/l)                 | 382  | 452  | 502  | 402  | 402  | 392  | 452  | 152  | 500 |
| Calcium (mg/l)                  | 95   | 145  | 157  | 101  | 120  | 111  | 117  | 41   | 100 |
| Magnesium (mg/l)                | 35   | 22   | 27   | 36   | 19   | 25   | 39   | 12   | 150 |
| Potassium (mg/l)                | 3.6  | 4.4  | 6.6  | 0.9  | 1.3  | 2.2  | 5.8  | 2.7  | 12  |
| Sodium (mg/l)                   | 30   | 56   | 47   | 76   | 38   | 28   | 41   | 14   | 200 |
| Sulfate (mg/l)                  | 101  | 60   | 75   | 48   | 344  | 87   | 72   | 29   | 250 |
| Nitrate (mg/l)                  | 6    | 18   | 14   | 5    | 2    | 12   | 12   | 1    | 50  |
| Bicarbonate (mg/l)              | 282  | 392  | 392  | 432  | 412  | 272  | 347  | 152  | 500 |
| Chloride (mg/l)                 | 23   | 49   | 59   | 37   | 11   | 25   | 37   | 6    | 250 |

Table 2 The Pearson correlation matrix to establish the relationship between different constituents of the Bhara Kahu groundwater.

|                  | Correlation matrix |      |           |            |                  |     |      |          |      |       |       |                 |                 |     |
|------------------|--------------------|------|-----------|------------|------------------|-----|------|----------|------|-------|-------|-----------------|-----------------|-----|
|                  | E C                | pH   | Turbidity | Alkalinity | HCO <sub>3</sub> | Ca  | Cl   | Hardness | Mg   | K     | Na    | SO <sub>4</sub> | NO <sub>3</sub> | TDS |
| EC               | 1                  |      |           |            |                  |     |      |          |      |       |       |                 |                 |     |
| pH               | -.70               | 1    |           |            |                  |     |      |          |      |       |       |                 |                 |     |
| Turbidity        | -.29               | .52  | 1         |            |                  |     |      |          |      |       |       |                 |                 |     |
| Alkalinity       | .86                | -.64 | -.29      | 1          |                  |     |      |          |      |       |       |                 |                 |     |
| HCO <sub>3</sub> | .86                | -.64 | -.29      | 1          | 1                |     |      |          |      |       |       |                 |                 |     |
| Ca               | .91                | -.79 | -.26      | .77        | .77              | 1   |      |          |      |       |       |                 |                 |     |
| Cl               | .86                | -.40 | -.12      | .59        | .59              | .80 | 1    |          |      |       |       |                 |                 |     |
| Hardness         | .95                | -.77 | -.21      | .81        | .81              | .94 | .78  | 1        |      |       |       |                 |                 |     |
| Mg               | .56                | -.17 | .074      | .41        | .41              | .28 | .43  | .57      | 1    |       |       |                 |                 |     |
| K                | .39                | .01  | .38       | .04        | .04              | .48 | .65  | .44      | .24  | 1     |       |                 |                 |     |
| Na               | .77                | -.37 | -.26      | .85        | .85              | .53 | .64  | .60      | .49  | -.054 | 1     |                 |                 |     |
| SO <sub>4</sub>  | .01                | -.43 | -.21      | .35        | .35              | .20 | -.38 | .16      | -.22 | -.34  | -.093 | 1               |                 |     |
| NO <sub>3</sub>  | .70                | -.52 | .03       | .33        | .33              | .75 | .82  | .69      | .25  | .66   | .31   | -.35            | 1               |     |
| TDS              | .99                | -.71 | -.27      | .87        | .87              | .92 | .86  | .95      | .52  | .37   | .78   | .029            | .71             | 1   |

acidic waters may dissolve the calcium from those rocks in the waters. The calcium and bicarbonate are found to be defining this groundwater and it is very similar to the groundwater of the Karst aquifers showing the activity and reactions pertaining to the CaCO<sub>3</sub> (Earl, 1982). The high ionic concentration of magnesium is indicative of dolomite and that is found

correlation matrices show that various physicochemical parameter pairs have significant positive correlations such as Bicarbonates – Alkalinity (r= 1.0), Calcium - EC (r =0.9), TDS – Hardness (r = 0.95), Calcium - Hardness (r = 0.94), Calcium-Chloride (r= 0.80) and Sodium-Bicarbonate (r = 0.85). The alkalinity has the strongest correlation due to the

effect of bicarbonates only as there are no carbonates in this groundwater. The other correlations reveal the calcium as the most effective ion for the hardness, EC and TDS. Strong correlation of chloride with calcium indicates noncarbonate hardness (Purandara and Vardarajan, 2003)

Similarly, substantial negative correlation has been found in EC – Ph ( $r = -0.7$ ), Sulfate – Chloride ( $r = -0.38$ ), Nitrate – Sulfate ( $r = -0.35$ ). Moreover, Nitrates have shown significant positive correlation with EC ( $r = 0.75$ ), Calcium ( $r = 0.75$ ) and Chloride ( $r = 0.83$ ) suggesting that the sources of Nitrates are anthropogenic including farm animals, fertilizers and manure (Chowdary et al.,2005; Khan et al.,2012).

A Piper trilinear diagram (Piper 1953) has been used to classify ground water on the basis of major ions from all samples. Based on this procedure, groundwater is categorized to have the Ca-HCO<sub>3</sub> type (Fig. 2). This typical hydrochemical facies type can be attributed to a shallow, recently infiltrated groundwater as per the concept of the evolution of the groundwater geochemistry by Chebotarev (1955). Now as per this concept the groundwater shows the reasons of the neutral pH and ionic concentrations below permissible limits.

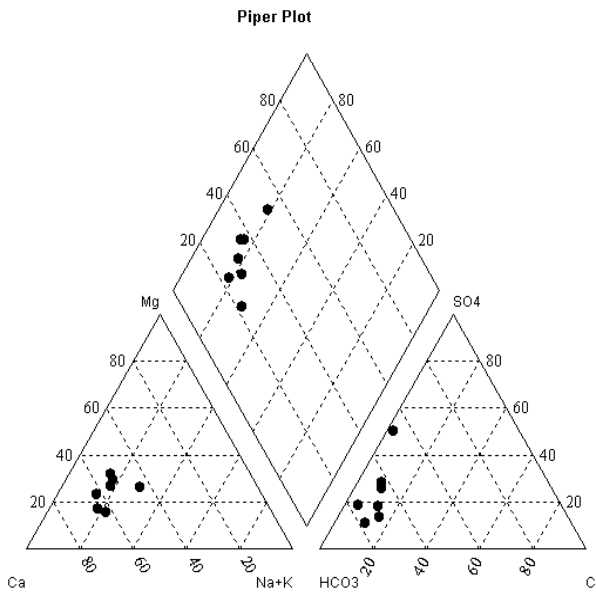


Fig. 2 The hydrochemical facies delineation using the piper hill diagram.

According to Wilcox (1948) diagram shown in Figure 3 that defines the salinity and the sodium hazard for determining the irrigation quality of the groundwater. The samples lie mostly in the C2 to C3 and S1 category respectively. The C2 to C3 category defines the groundwater with medium to high salinity range. The S1 describes the low sodium or Alkali hazard from the use of this water. The salinity of the groundwater may be reduced by the conjunctive use of the fresh water and groundwater.

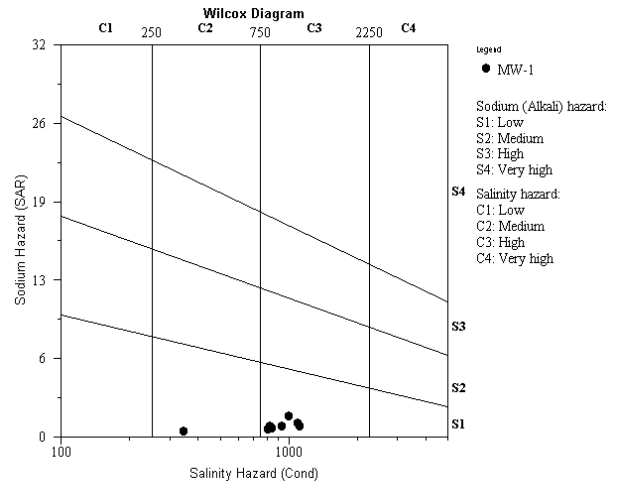


Fig. 3 Wilcox diagram showing the suitability of the groundwater for irrigation.

**Conclusion**

Based on water quality assessment and hydrochemistry studies, it is concluded that the groundwater in the area of Bhara Khau, Islamabad, Pakistan in the shallow aquifers is not polluted. However, it can be used for drinking after mild treatment for calcium. The geochemical evolution of groundwater describes it to be of Ca-HCO<sub>3</sub> type showing a single aquifer having a younger groundwater showing an impact of the surrounding calcium carbonate bearing rocks. The suitability of the groundwater determined by the EC and the sodium hazard determines it to be safe, if diluted, to decrease the effects of high salinity on the soil and the crops. The evidence of mild anthropogenic effect is also found in this groundwater. However, a detailed and regular monitoring is needed for the assessment of the changes in the groundwater quality.

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