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ABSTRACT

Das TK, Mamun MA, Shaibur MR (2019) Hydro-geochemistry and quality assessment of deep groundwater in Shyamnagar Upazila, South-Western Bangladesh. *Int. J. Expt. Agric.* 9(1), 14-21.

The Shyamnagar Upazila is located in southern most part of Bengal basin, which is characterized by extensive natural geochemical activities, brackish water and huge organic deposits. The hydro-geochemical data were collected from 50 deep aquifer water samples during July, 2018 were used for evaluating water quality and to determine process that control water chemistry. The collected samples were analyzed for pH, electric conductivity (EC), total dissolve solids (TDS), salinity, total hardness (TH), Na^+, K^+, Ca^{2+}, Mg^{2+}, SO_4^{2-}, NO_3^-, PO_4^-, Cl^-, and HCO_3^- concentration. The results illustrated that the dominations were in the order of $Na^+>Ca^{2+}>Mg^{2+}>K^+$ for cations and $Cl^->HCO_3^->PO_4^->NO_3^->SO_4^{2-}$ for anions. The scatter diagram represented that Na^+ion in groundwater comes from silicate weathering while both silicate and carbonate weathering were equally responsible for Ca^{2+} and Mg^{2+} ion. The piper diagram indicated that Na-HCO_3, mixed $NaCaHCO_3$ and NaCl are dominated in the hydro-geochemical facies. The Gibbs diagram showed that rock weathering was the main source of ions in groundwater, while sea water intrusion and precipitation has negligible effect on it. The Wilcox diagram indicated that most of the water sources were suitable for irrigation. The controlling factor of groundwater chemistry was mostly related to geologic factors, while the anthropogenic factors have not any significant effects.

Key words: *coastal zone, deep groundwater, hydro-geochemistry, quality assessment*

INTRODUCTION

Water is the most fundamental prerequisite for life on earth. In recent times, the provision of safe drinking water remains a major target for both the developed and developing countries. In the recent past three decades, excessive installation of rural groundwater supplies through tube wells have led to increasing contamination in groundwater (Mostafa *et al.* 2017; Gupta *et al.* 2009). This is the exact scenario of rural Bangladesh. Groundwater is used extensively for drinking water throughout Bangladesh. In the coastal region most of the groundwater used for water supply is pumped from the top 150 m, but many them are saline (Chowdhury 2010). Being a low-laying deltaic country of high density of population, Bangladesh is susceptible to a variety of environmental stresses, which can exacerbate the difficulties accessing the quality of potable water especially in coastal zone (Abedin *et al.* 2014). For example, the south-western part of Bangladesh was severely affected by Cyclone Sidr in 2007 and cyclone Aila in 2009. These types of disaster in the Southwestern parts of Bangladesh may cause due to climate change (Shaibur *et al*. 2017a). Due to Sidr and Aila, many drinking water sources were inundated with saline tidal water and became unusable for drinking purposes (Food & Agricultural Organization, 2009; Mallick *et al.* 2011). In the certain areas of coastal Bangladesh, both shallow and deep tube wells are off-use due to high salinity and natural causes as in the groundwater and it is for salinity rather than arsenic (Islam *et al.* 2011). Not only groundwater, the soils of some coastal Upazilas (e.g. Shyamnagar) of Bangladesh is saline even after few years of Sidr and Aila (Shaibur *et al.* 2017b). The groundwater quality depends on the quality of recharged water, atmospheric precipitation, inland surface water and on sub-surface geochemical processes. Temporal changes in the origin and constitution of the recharged water, hydrologic and human factors, may cause periodic changes in groundwater quality (Vasanthavigar *et al.* 2010).

Geochemical process, occurring within the groundwater and their reactions with the aquifer materials are responsible for changes in groundwater chemistry and quality (Rao and Rao, 2009). Some researchers reported that, groundwater salinization is due to over pumping, excess irrigation, fertilizer leaching and nitrate pollution from wastewater leakage (Mukherjee *et al.* 2006; Umezawa *et al.* 2009). Therefore, it is impossible to control the dissolution of undesirable constituents in the waters once they enter into the ground (Johnson 1979). Therefore, a basic concept of groundwater chemistry is a pre-requisite condition for water resource management. The groundwater is an important source for drinking, agricultural, industrial and commercial purpose in Bangladesh (Oladipo *et al.* 2011). It is the single largest source of drinking water in most of the developing countries and estimated that approximately one-third of the world's population is depending on groundwater where the general assumption of groundwater is being safe to drink (Nickson *et al.* 2005). The groundwater is quite different from other water sources as it doesn't contain any microbial contamination and its availability plays a vital role in socio-economic development of any country.

A lot of research has been conducted in coastal zone of Bangladesh with very few in south-western parts for analysis of deep aquifer groundwater. A complete geochemical knowledge of groundwater is important for sustainable groundwater resource development, that's why a study on hydro-geochemistry and groundwater quality assessment was conducted. The aim of the study was to determine the groundwater type and hydro-

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geochemical process controlling the groundwater quality to determine the suitability of groundwater for drinking purpose.

MATERIALS AND METHODS

Study Area

The study area was Shyamnagar upazila under Satkhira district in Bangladesh, which is situated in south-western corner of the country and very close to Sundorban mangrove forest and Bay of Bengal (Fig. 1). The geological position makes it hard to reach area with acute scarcity of saline free water sources. It lies between 21º36' and 22º54' N latitudes and between 88º54' and 89º20' E longitudes (Bangladesh Bureo of Statistics, 2013). The water sample were collected from six union which were selected depending on geological position, drinking water scarcity and hard to reach area.

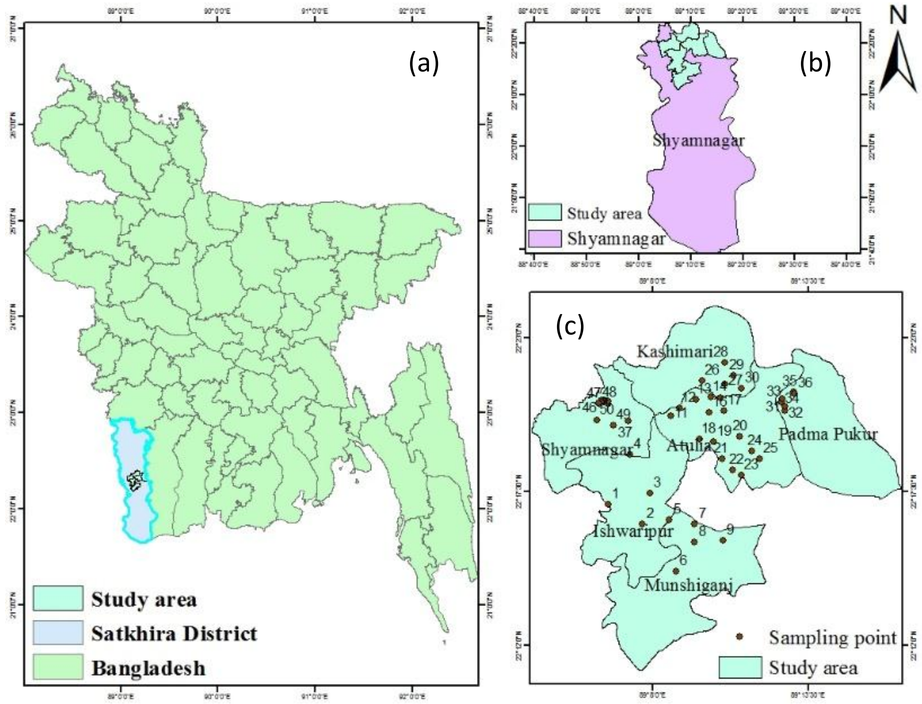

Fig. 1. Groundwater sample location and geology map of the study area.
(a) Bangladesh, (b) Shyamnagar upazila, and (c) Sampling point

Water Sample Collection and Analysis

A total of 50 water samples were collected from deep tube well during July, 2018. The depth of all tube well varied between 450 to 600 feet's. The samples were collected in one litter potable water bottles. At first the bottle were washed with tap water and socked in 0.1 N HNO_3 for 24 h. During sample collection the bottle were prewashed and rinsed properly with sample water to avoid contamination. Before sample collection, tube well were pumped exact times with respect to the depth of the aquifer in feet (i.e. a 500 feet tube well was initially pumped for 500 times). After collection of water sample, it was immediately carried to the Environmental Chemistry Laboratory of Jashore University of Science and Technology and analyzed. The water temperature, pH, EC and TDS were measured at the sampling site using Microprocessor pH meter (model- HANNA instrument pH 211) and conductivity meter (model- HI 8033). The measurement of Na^+ and K^+ were done by flame photometric method (flame photometer- PEP7). The TH, Ca^{2+}, Mg^{2+} and HCO_3^- were analyzed by titration colorimetric method and Cl^- by Ergonometric method. The NO_3^-, PO_4^-, and SO_4^{2-} were analyzed by Turbid metric method with Spectrophotometer (model- UV-visible spectrophotometer, helios 949923045811) (American Public Health Association; APHA 1995).

Data Analysis

The water quality data were analyzed by MS Excel 2017, SPSS version 20 and Aqua cham Version 4. Hydro-chemical classification and groundwater evaluation were discussed by using Carbonate vs Silicate Weathering, Gibbs Diagram, Piper Diagram and Wilcox Diagram. For drinking water quality assessment, the results were compared with World Health Organization (WHO), United States Environment Protection Agency (USEPA) and Bangladesh Standard and Testing Institute (BSTI) drinking water quality. The Gibbs Diagram is widely used to establish the relationship of water composition and aquifer lithological characteristics (Gibbs 1970). Gibbs ratio I (for anion) = $Cl^-/(Cl^-+HCO_3)$; Gibbs ratio II (for cation) = $Na^+/(Na^++Ca^{+2})$, where all the ionic concentration were expressed in meq/l. The Wilcox Diagram represents the suitability of water for irrigation and domestic purposes (Wilcox 1955).

RESULTS AND DISCUSSION

General Hydro-Geochemistry

The statistics of the water chemistry is represented in Table 1. The pH values do not show any meaningful changes among the groundwater samples. It ranges from 7.23 to 8.03, which indicate that the groundwater were slightly alkaline in nature. The pH value in all the water samples were within WHO (WHO 2008) and BSTI drinking water quality standard. The EC values show a long range from 248 to 4532 μscm^{-1}. A similar result was found in another study in Shyamnagar area (Das *et al.* 2017). The EC value signifies the amount of inorganic pollutant and TDS in water (Mostafa *et al*. 2017). High EC values indicate a high ion concentration or a high content of dissolved solids in the groundwater (Yadav *et al*. 2018).

Table 1. Characteristics of deep aquifer water samples

Parameter	Min	Max	Mean ± SD	Standard	
				WHO	BSTI
pH	7.23	8.03	7.69 ± 0.22	6.5-8.5	6.5-8.5
EC	248	4532	1395 ± 1031	1000-1500	2000
TDS	161	2929	905.88 ± 664.57	1000	1000
Salinity	0.1	2.5	0.67 ± 0.65	-	-
Na^+	26.13	281	106.63 ± 48.91	200	200
K^+	2.12	41.57	9.49 ± 6.52	12	12
Ca^{2+}	24	224	90.56 ± 53.13	75	75
Mg^{2+}	12	91.2	36.08 ± 20.83	30	30-35
PO_4^{3-}	0.01	6.1	1.32 ± 2.04	45	6
SO_4^{2-}	0.02	8.31	0.92 ± 1.75	200	200
NO_3^-	0.54	3.23	1.02 ± 0.61	10	10
Cl^-	17.73	1134	539.85 ± 288.99	200	150-600
HCO_3^-	115.9	585.6	373.66 ± 107.22	200-600	600

BSTI = Bangladesh Standard and Testing Institute; SD = Standard Deviation, TDS = Total Dissolve Solids, WHO = World health Organization. N.B: Unit: EC (Electrical Conductivity) = μscm^{-1}, Salinity = ppt & others = mg/l.

The TDS values of the water samples ranged from 161 to 2929 mg/l with the mean value of 905 (±664.57) mg/l. Among 50 water samples, 12 exceeded the limit of WHO and BSTI drinking water quality standard. The water with TDS up to 500 mg/l is considered desirable for drinking, 500–1000 mg/l is permissible for drinking, up to 3000 mg/l is useful for irrigation and the greater than 3000 mg/l is unsuitable for drinking and irrigation purposes (Nadeem *et al.* 2016). The mean concentration of salinity was 0.66 (±0.65) ppt.

Major Cation Chemistry

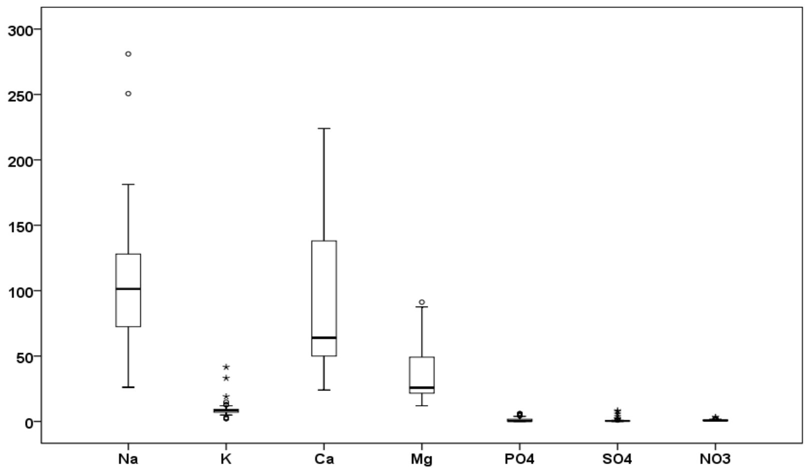

Fig. 2. Box plot for major ions (in mg/l) of deep aquifer water sample

The concentration of major cations and anions in groundwater sample were represented in Fig. 2. The mean concentration of Na^+ in the study area was found with an average of 106.63 (±48.91) mg/l. There is no internationally recognized standard for Na^+, while USEPA suggested that, Na^+ concentration in drinking water didn't exceed 20 mg/l and the entire water sample exceed the limit (USEPA 1994). The Ganges alluvial sediments consist of feldspars ranged from 6.0 to 12.0 percent at different locations along its course. The results suggested that Na^+ was derived from weathering of halite and feldspar rocks sources in this area (Tripathi *et al.* 2007). The K^+ concentration in the water sample varied from 2.12 mg/l to 41.57 mg/l (Fig. 2). The BSTI and WHO drinking water standard for K^+ in drinking water was 12 mg/l and one-fourth of the samples exceeded the limit.

The Ca^+ ion concentration in water samples ranged from 24 to 224 mg/l and most of the samples were within standard limit. While the magnesium concentration ranged from 12.0 to 91.20 mg/l with an average value of 36.08 (±20.83) mg/l. Among 50 water samples, 19 exceed the limit of BSTI and WHO drinking water quality standard. Magnesium usually occurs in lesser concentration than calcium due to the fact that the dissolution of Mg-rich minerals is slow process and that of Cais more abundant in the earth's crust (Garg *et al*. 2009).

Major Anion Chemistry

The water samples contains negligible amount of PO_4^{3-} with mean value of 1.37 (±2.04) mg/l. Phosphate occurs widely in nature such as plants, micro-organisms, animal wastes and so on. Phosphate also occurs in ground water from domestic sewage, detergents, fertilizers and industrial waste water (EPA 2001). The value of NO_3^-in water samples ranged from 0.5 to3.43 mg/l, while the BSTI and WHO recommended value of NO_3^- in drinking water was 45 mg/l. The low concentration of NO_3^- in water indicates the lack of bacterial mediated reaction in the aquifer (Chauhan *et al.* 2009). The mean concentration of SO_4^{2-} in study area was 0.92 (±1.75) mg/l and all the water samples were within recommended standard. The results were similar to another study of Shyamnagar (Das *et al.* 2017) and Jashore areas (Shaibur *et al.* 2012).

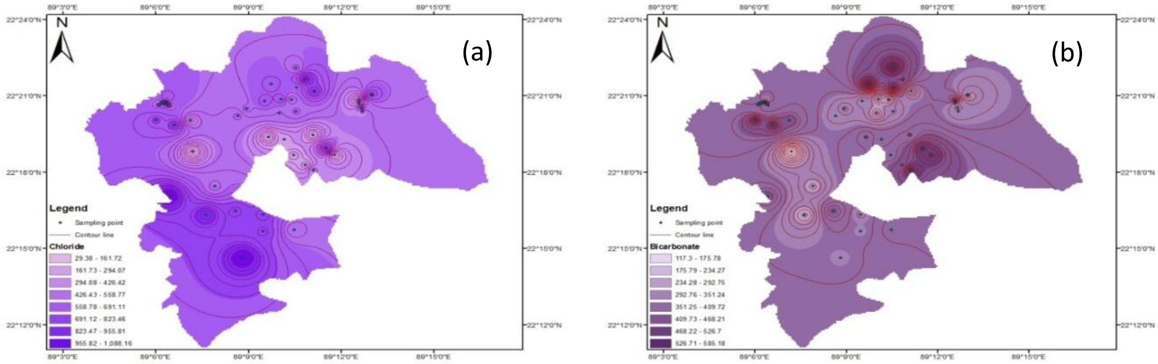

Fig. 3. Spatial distribution map of (a) chloride and (b) bicarbonate concentrations in study areas

The Cl^- was the most abundant ion in water samples in the study area. The minimum value of Cl^- was 17.73 and maximum 1134.40 mg/l, while the average value was 539.85 (±288.99) mg/l. About 50% of water sample in the study area exceed the BSTI and WHO drinking water quality standard. The Cl^- in groundwater arises from natural geochemical activities and leaching from upper soil layers (Mostafa *et al.* 2017). The mean concentration of HCO_3^- in ground water samples were 373.66 (±107.21) mg/l (Fig. 3). If the HCO_3^- concentration in drinking water exists within 300 mg/l, it has no adverse health impact. If the concentration of HCO_3^-ishigher than 300 mg/l, it leads to kidney stones in the presence of the higher concentration of Ca, especially in dry climatic regions (Mostafa *et al.* 2017).

Scatter Diagram

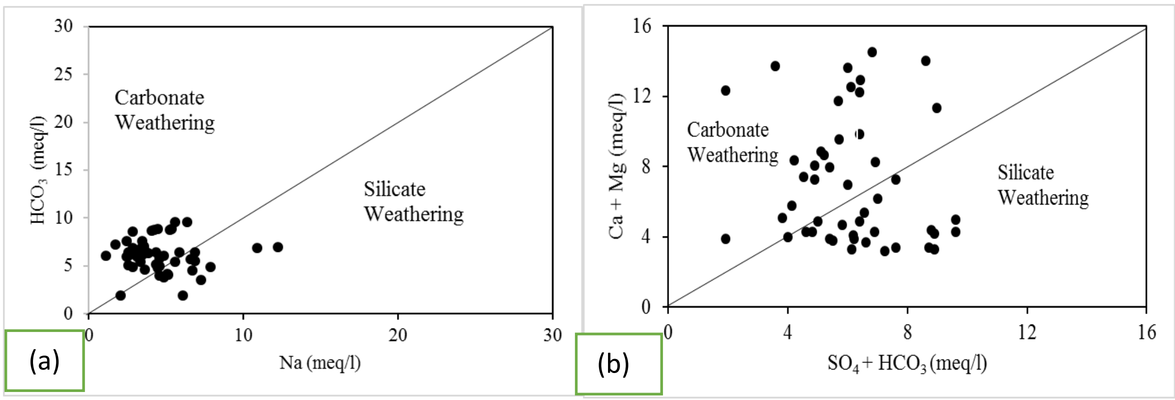

Fig. 4. The scatter diagram (a, b) for carbonates weathering VS silicate weathering process of groundwater samples

The HCO_3^- VS Na^+ scatter diagram (Meybeck 1987) shows that, two thirds of the sample falls above the 1:1equiline, which indicated that carbonate weathering is the dominate process for releasing Na^+ ion in groundwater. More specifically about 70% of Na^+ ions in groundwater originate from weathering of carbonate rocks such as dolomite, limestone and gypsum, while 30% originate from silicate weathering (Fig. 4a). The (Ca^{+2} + Mg^{+2}) VS (SO_4^- + HCO_3^-) scatter diagram (Datta and Tyagi, 1996) represented that, half of the water samples were above the 1:1 equiline. This indicated that, silicate and carbonate weathering were equally responsible for releasing Ca^+ and Mg^{2+} in deep aquifer groundwater (Fig 4b). The increasing HCO_3^- concentration compared to Na^+ concentration in the groundwater indicates the dominancy of silicate weathering process; it is well supported by a high concentration of HCO_3^- (Elango *et al.* 2003).

Piper Diagram

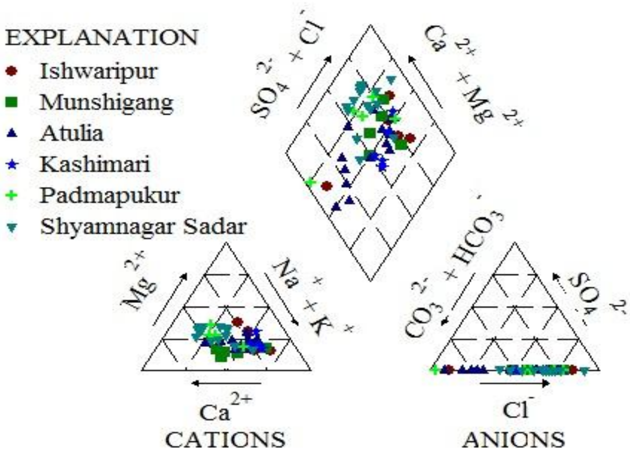

Fig. 5. Piper diagram showing the dominant water type within study area

The Piper Trilinear Diagram (Piper 1944) shown in Fig. 5, indicated that Na-HCO_3, mixed $NaCaHCO_3$ and NaCl type domination in hydro-geochemical facies. The figure also indicates that silicate weathering and rock water domination is the major influencing factors for increasing ion concentration in groundwater. The combination of Na–HCO_3 and $NaKHCO_3$ fields in the piper diagram are indicative of natural geo-chemical process in the study area. (Jeevanandam *et al.* 2006).

Gibbs Diagram

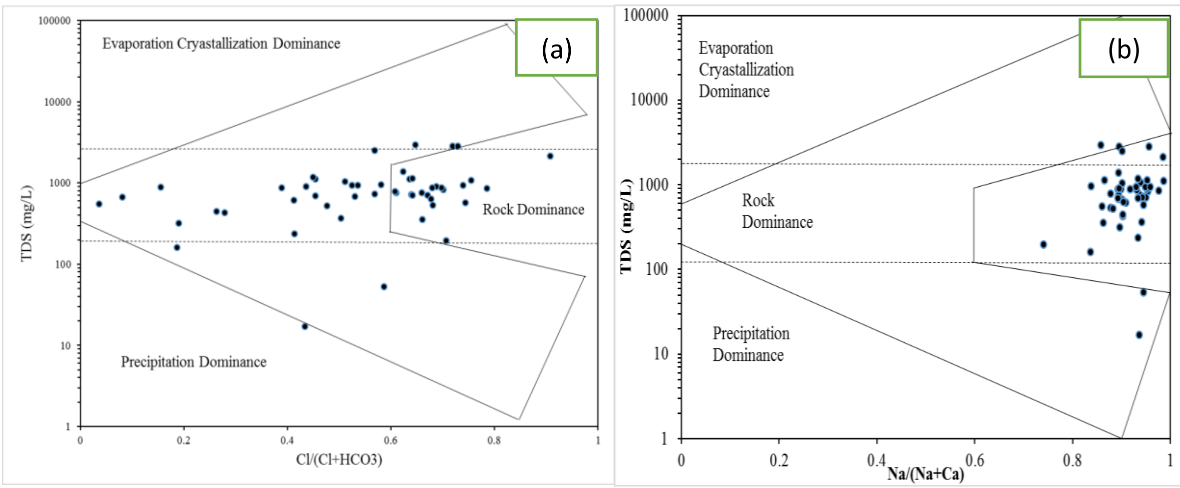

Fig. 6. Gibbs plot (a, b) showing major processes controlling groundwater chemistry

The Gibbs Diagram is used to detect the mechanisms that control the hydro-chemical components in groundwater (Sonkamble *et al*. 2012). Three distinct plot, precipitation dominance, rock dominance and evaporation crystallization dominance were observed in each Gibbs plot. Fig. 6 showed that, 90% of water samples were under rock dominance area, while 6% was evaporation crystallization dominance and 4% was precipitation dominance. The figure illustrated that, the majority of ions in deep aquifer groundwater came from rock weathering and negligible percentage came from sea water intrusion and precipitation.

Wilcox Classification of Water Samples

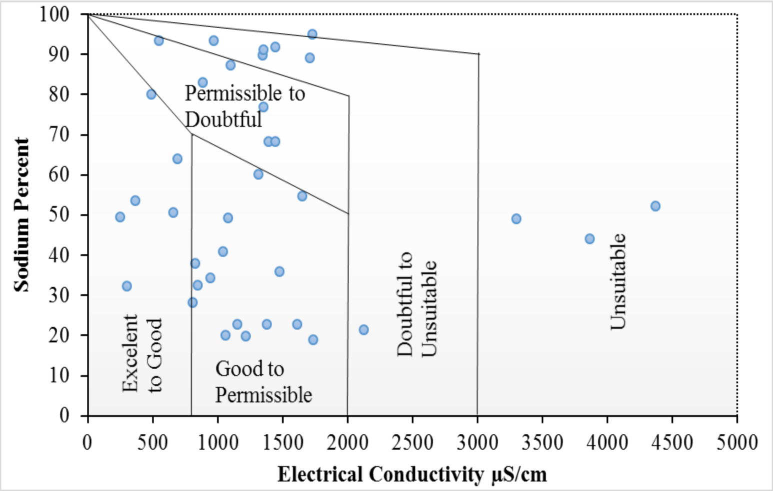

Fig. 7. Wilcox diagram indicating groundwater suitability for agricultural use

The Fig. 7 illustrated that, 12% of the water samples clustered in the zone of excellent to good, 30% was good to permissible, 12% was permissible to doubtful, 14% was doubtful to unsuitable and remaining 6% was unsuitable for agricultural purpose. Based on Wilcox classification most of water samples were suitable for irrigation in every types of soil. The EC and Na^+ played a vital role in suitability of water for irrigation (Rao 2005).

CONCLUSION

The results revealed that the deep aquifer groundwater was slightly alkaline in nature. The EC and TDS in most of the samples were within BSTI and WHO drinking water quality standard. The concentration of Na^+, Ca^{2+}, Mg^{2+} and K^+ in two third of water samples were within drinking water quality standard. Among the anions the concentration of Cl^- and HCO_3^- were the dominating species and about half of the water samples exit the prescribed drinking water quality standard of BSTI and WHO. The Na^+ in the groundwater originated from weathering of carbonate rocks; whereas Ca^+ and Mg^{2+} originated from weathering of both carbonate and silicate rocks. The groundwater chemistry was mainly dominated by Na^+, Ca^{2+}, Cl^- and HCO_3^-. The minerals in the water came from weathering of underground bedrock. On the basis of Wilcox diagram, the deep aquifer water was suitable for irrigation. The evaporation concentration and groundwater mixing had very negligible effect on chemistry of groundwater in Shyamnagar area compared to rock dissolution. The natural geochemical activities were the controlling factors of deep aquifer groundwater chemistry compared to anthropogenic activities.

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