Assessment of Groundwater Quality of Agra District for the Irrigation Purpose

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ABSTRACT

Groundwater quality of Agra district has been assessed considering twelve water quality parameters viz. pH, electrical conductivity (EC), total dissolved solid (TDS), chloride (Cl^-), bicarbonate (HCO_3^-), sulfate (SO_4^{2-}), silicon (Si), iron (Fe), aluminium (Al), calcium (Ca^{++}), magnesium (Mg^{++}) and sodium (Na^+). Data on groundwater quality of fifteen blocks of the Agra district were collected for nine years (2006-2014) from the Ground Water Department, Government of Uttar Pradesh. The data are investigated using Wilcox and Piper diagrams with the help of Aquachem 2011.1 software. The assessment on suitability of groundwater quality for the irrigation purpose is done using sodium percentage (Na%), Sodium Absorption Ratio (SAR) and Residual Sodium Carbonate (RSC) for all the blocks. The results show that groundwater of various blocks of Agra district is of Naz - Cl^-, Ca^{2+} -Na^+ - HCO_3^-, Ca^{2+}-Mg^{2+} - Cl^-, Ca^{2+} - HCO_3^-, Ca^{2+} - Cl^-, Na^+ - Cl^-, Ca^{2+} - Mg^{2+} - Cl^- - SO_4^{2-} and Ca^{2+}- Na^+ - HCO_3^- type. It is also found that the groundwater quality of the blocks Barauli Ahir, Fatehapur Sikari, Saiyan, Achhnera, Shamsabad, Khandouli, Pinahat, Jaitpur Kalan and Bah falls under *very good* to *medium* category and can be used for the irrigation purpose. However, the groundwater quality for the blocks Bichpuri, Akola, Fatehabad, Khairagarh, Etmadpur and Jagner falls under Medium to *very bad* category and hence cannot be used for the irrigation purpose. The outcome of the study would be helpful to the farmers, policy makers and water management authorities in planning and management of irrigation water.

Keywords: Groundwater, water quality, irrigation, Agra

INTRODUCTION

Groundwater is an important source of fresh water supply for use in domestic, agricultural and industrial sectors in major part India. Inconsistent monsoon rainfall, deficient surface water and Agra district has a continental sub-tropical climate with long hot summers from April to September when temperature reaches as high as 45 °C. During summers dry winds (heat waves) blow in this region. During monsoon months from July to September, about 670 mm of rainfall occurs. The maximum temperature during summer is 45 °C and minimum temperature is about 21.9 °C and during winter maximum temperature goes up to 31.7 °C and minimum temperature up to about 4.2 °C.

METHODOLOGY

The water quality data are analysed using standard procedures for twelve water quality parameters viz. pH, electrical conductivity (EC), total dissolved solid (TDS), chloride (Cl^-), bicarbonate (HCO_3^-), sulfate (SO_4^{2-}), silicon (Si), iron (Fe), aluminium (Al), calcium (Ca^{++}), magnesium (Mg^{++}) and sodium (Naz) of fifteen blocks of the Agra district collected for nine years period from 2006 to 2014 from the Ground Water Department, Government

of Uttar Pradesh. In order to check the results of laboratory analysis, ionic balance has also been performed and the error is found less than 10%.

Piper Trilinear Diagram

The concept of hydro-chemical facies can be used to denote the diagnostic chemical characteristics of water in the hydrological system. The facies reflect the effect of chemical processes occurring among the minerals within the lithological frame work and in the ground water. The diagram is useful in graphically presenting a group of analysis on the same plot. The Piper trilinear diagram consists of two lower triangular fields, one at the left and another at the right, respectively and a central diamond-shaped field. All three fields have scales reading divided in 100 parts. The percentage-wise reacting values of the three cations (Ca^{2+}, Mg^{2+}, $Na^+ + K^+$) and three anions (HCO_3^-, SO_4^{2-}, Cl^-) are plotted as a single point according to the conventional trilinear coordinates at lower left and right triangles, respectively. These are projected upwards parallel to the sides of the triangles so as to give a point in the central diamond-shaped field. This point indicates the overall chemical character of the groundwater. Further, the position of this point indicates the relative composition of groundwater in terms of cation-anion pairs that correspond to the four vertices of the field. The three areas of plotting show the essential chemical character of groundwater according to the relative concentrations of its constituents as shown in Figures 2 and 3.

The water quality is evaluated on the basis of Sodium Absorption Ratio (SAR), Sodium Percent and Residual Sodium Carbonate (RSC), Wilcox plot.

Sodium Absorption Ratio (SAR)

Sodium percentage in the water can displace the calcium and magnesium ions in the soil. This will cause a decrease in the ability of the soil to form stable aggregates and a loss of soil structure and tilt. This will also lead to a decrease in infiltration and permeability of the soil leading to problems with crop production. Todd (1980)[13] defined soluble sodium percentage (SSP) or Na% as

$$SAR = \frac{Na^+}{\sqrt{(Ca^{2+} + Mg^{2+})/2}} \qquad ...(1)$$

where Na^+, Ca^{2+} and Mg^{2+} are the percentages of concentrations in milli-equivalents per litre.
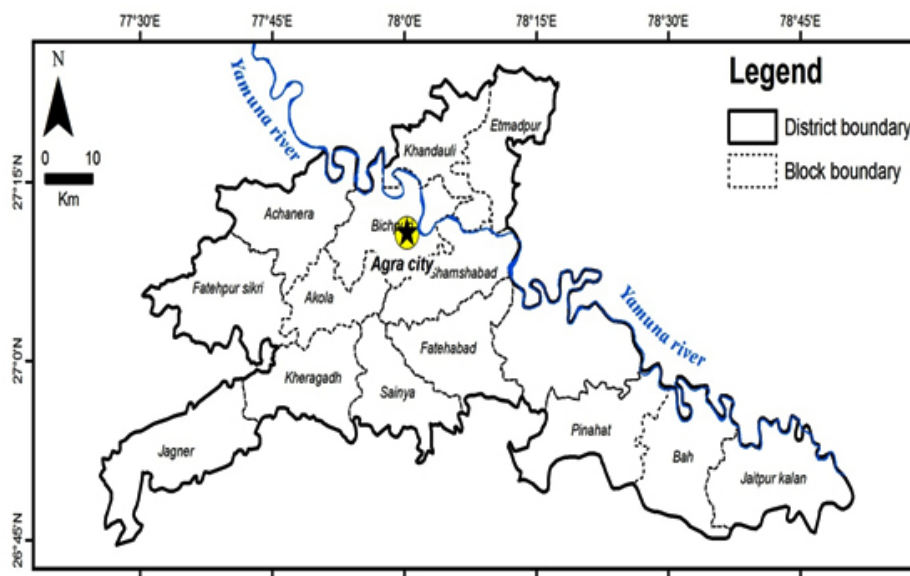

Fig. 1: Map of Agra district showing various blocks and the Yamuna River

Sodium Percentage (Na %)

Sodium percentage in the water can displace the calcium and magnesium ions in the soil. This will cause a decrease in the ability of the soil to form stable aggregates and a loss of soil structure and tilt. This will also lead to a decrease in infiltration and permeability of the soil leading to problems with crop production. Todd (1980)[13] defined soluble sodium percentage (SSP) or Na% as

$$Na\% = \frac{Na^+ + K^+}{Ca^{2+} + Mg^{2+} + Na^+ + K^+} \times 100$$

...(2)

where K^+ is the percentage of concentration in milli-equivalents per litre.

Residual Sodium Carbonate (RSC)

When the carbonate concentration becomes too high, the carbonates combine with calcium and magnesium to form a solid material which settles out of the water. This excess is denoted by RSC and is expressed as

$$RSC = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$$

...(3)

where CO_3^{2-} and HCO_3^- are the percentages of concentrations in milli-equivalents per litre. A Wilcox plot is a simple scatter plot of Sodium Hazard (SAR) on the Y-axis versus Salinity Hazard (conductivity) on the X-axis and is used to determine the viability of water for irrigation purposes.

Criteria for Assessment of Suitability of Water for the Irrigation Purpose

CGWB and CPCB (2000) has defined the criteria for assessment of suitability of water for the irrigation purpose with respect to electrical conductivity, sodium content, SAR and RSC as given in Table 1.

It is obvious from Table 1 that if the value of above-mentioned parameters is less, the water will be more suitable for the irrigation use. In the present paper, the groundwater quality has been assessed block-wise following the criteria specified in Table 1.
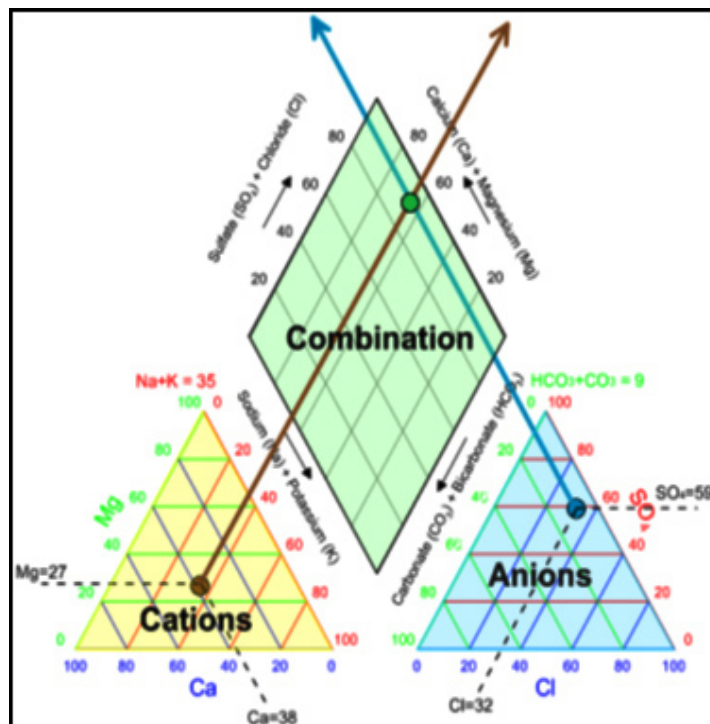

Fig. 2: Representation of water quality variables in the Piper trilinear diagram (http://www.goldensoftware.com)

RESULTS AND DISCUSSION

The water quality characterization and assessment on suitability for the irrigation purpose has been done using the Wilcox and Piper diagram, RSC, SAR and EC. Wilcox and Piper diagrams have been prepared using Aquachem 2011.1 software available at the Centre of Excellence for Advanced Groundwater Research (CEAGR) of National Institute of Hydrology (NIH), Roorkee. The SAR and RSC values have been computed using equation (1) and (3), respectively. In order to plot the Piper and Wilcox diagram for each block of the Agra district, the time series water quality data for the period 2006 to 2014 has been averaged out block-wise. The times

series average data are then plotted in the Piper and Wilcox diagram and are shown in Figure 4 and 5.

Figure 4 shows that for the Achhnera block anions ($HCO_3^-+SO_4^{2-}$) are 42% and cations ($Mg^{2+} + Na^+$) are 82%, for Akola anions are 25% and cations are 82%, for Bah anions are 74% and cations are 65%, for Barauli Ahir anions are 80% and cations are 65%, for Bichpuri anions are 85% and cations are 50%, and for Etmadpur anions are 42% and cations are 82%. Fatehabad anions are 46% and cations are 85%, for Fatehapur Sikari anions are 46% and cations are 85%, for Jagner anions are 40% and cations are 82%, for Jaitpur Kalan anions are 76% and cations are 70%, for Khairagarh anions are 46% and cations are 78%, for Pinahat anions are 54% and cations are 74%. For Saiyan anions are 40% and cations are 82%, for Shamsabad anions are 52% and cations are 82%, and for Khandouli anions are 56% and cations are 74%.

In overall it is found that the water facies of the blocks Achhnera, Akola, Bichpuri, Etmadpur, Fatehabad, Fatehapur Sikari, Jagner, Jaitpur Kalan, Khairagarh and Saiyan is Ca^{2+} - HCO_3^- type and Barauli Ahir, Shamsabad, Pinahat, Bah and Khandouli is mixed Ca^{2+} -Mg^{2+} -Cl^- type.

Table 1: Guidelines for the evaluation of irrigation water quality

Water class	Na (%)	EC (µS/cm)	SAR	RSC (meq/L)
Excellent	< 20	< 250	< 10	< 1.25
Good	20-40	250-750	10-18	1.25-2.0
Medium	40-60	750-2250	18-26	2.0-2.5
Bad	60-80	2250-4000	> 26	2.5-3.0
Very bad	> 80	> 4000	> 26	> 3.0

A = Mg^{2+} Type
B = Ca^{2+} Type
C = No Dominant Type
D = Na^+/K^+ Type
E = SO_4^{2-} Type
F = HCO_3^- Type
G = No Dominant Type
H = Cl^- Type
I = Mixed Ca^{2+}-Mg^{2+}-Cl^- Type
J = Ca^{2+}-HCO_3^- Type
K = Na^+-Cl^- Type
L = Mixed Ca^{2+}-Na^+-HCO_3^- Type
M = Ca^{2+}-Cl^- Type
N = Na^+-HCO_3^- Type
1 = Ca^{2+}-Mg^{2+}-Cl^--SO_4^{2-} Type
2 = Ca^{2+}-Mg^{2+}-HCO_3^- Type
3 = Na^+-K^+-Cl^--SO_4^{2-} Type
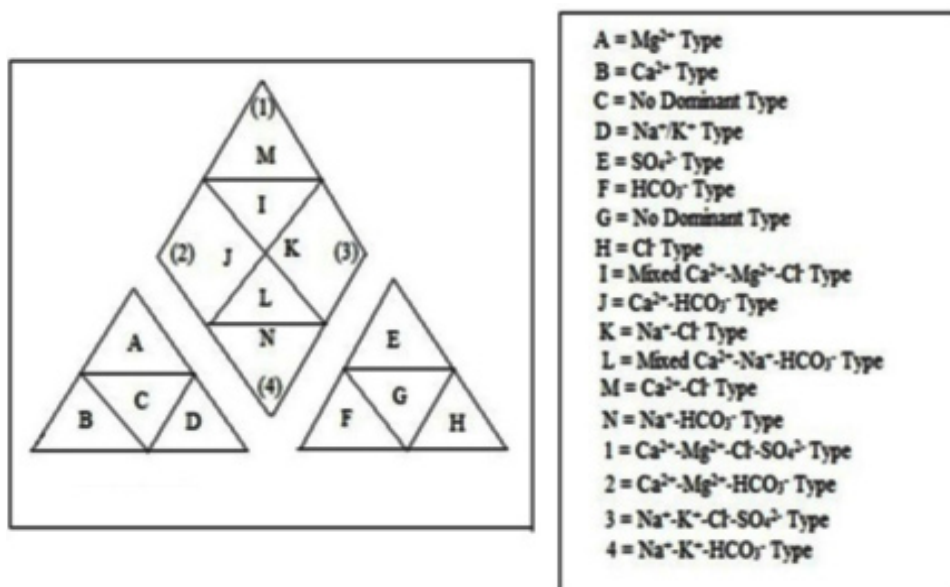4 = Na^+-K^+-HCO_3^- Type

Fig. 3: Pictorial representation of various groundwater facies (Manoj et al., 2013)8

The groundwater quality results are also plotted in Wilcox diagram for all the blocks of Agra district as shown in Figure 5. It is seen from Figure 5 that the groundwater quality data for majority of the blocks of the Agra district falls under S1 and S2 categories of Sodium Hazard (low to medium sodium hazard) except one block (Khairagarh) in the S4 category which indicates very high sodium hazard. On the other hand, groundwater quality data of majority of the blocks falls under the C3 and C4 salinity hazard which indicates high to very high salinity hazard except for Jaitpur Kalan block which falls in the C2 category of medium salinity hazard. In overall, the groundwater quality of the Agra district is characterized as C3S1 and C4S2 type.

Evaluation of the groundwater quality
The electrical conductivity of the blocks Barauli Ahir, Fatehapur Sikari, Shamsabad, Khandouli, Pinahat, Bah and Jaitpur Kalan is found up to 2,250 µmho/cm which depicts that the quality of water as *Medium*

to Excellent. However, the electrical conductivity of the blocks Bichpuri, Akola, Saiyan, Fatehabad, Achhnera, Khairagarh, Etmadpur and Jagner is found more than 2,250 µmho/cm which indicates the quality of water as *Bad to Very Bad*.

The sodium percentage of the blocks Barauli Ahir, Fatehapur Sikari, Shamsabad, Khandouli, Pinahat, Etmadpur, Jaitpur Kalan, Jagner, Bah, Saiyan and Fatehabad is found up to 60% and indicates the quality of water as *Medium to Excellent*. However, the sodium percentage of the blocks Akola, Achhnera, Khairagarh and Bichpuri, varies from 60 to more than 80% which indicates the quality of water *Bad to Very Bad*.

SAR of all the blocks is found up to 26 and indicates the quality of water *Medium to Excellent*, except for the block Khairagarh which shows SAR value more than 26 having water quality *Very Bad*. RSC value of all the blocks of the district is found less
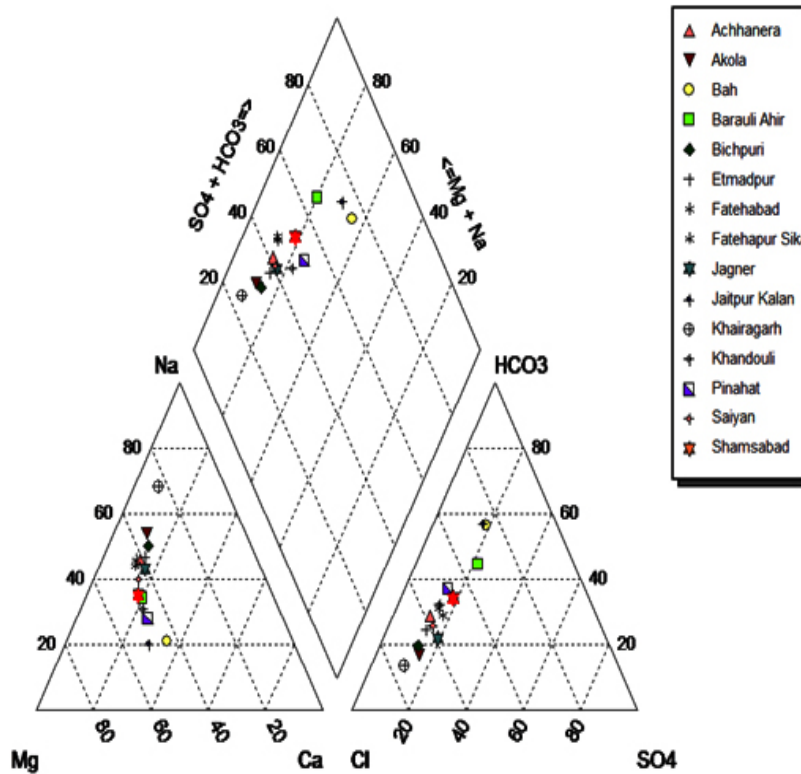

Fig. 4: Piper diagram showing groundwater quality of various blocks of the Agra district
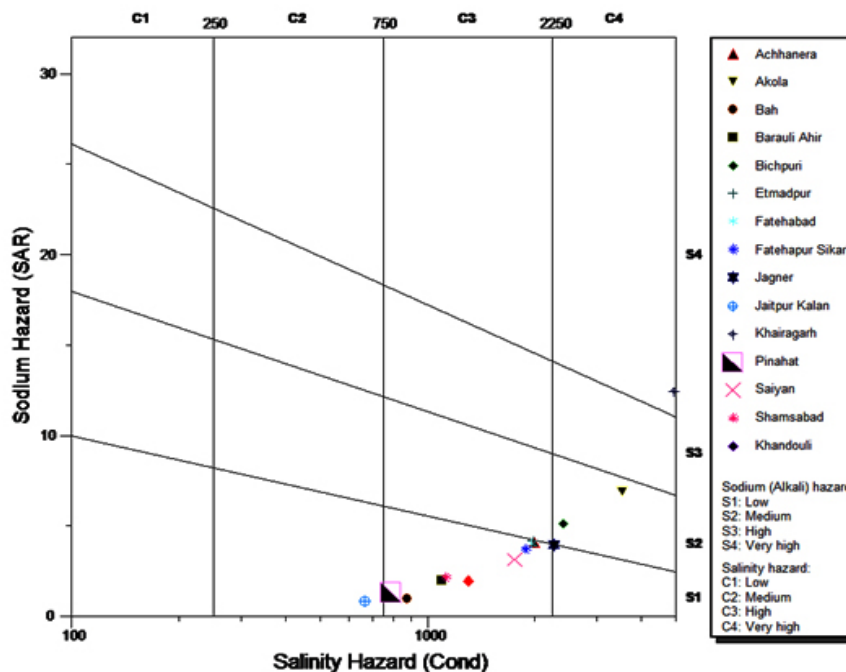
**Fig. 5: Wilcox diagram showing groundwater quality of]
various blocks of the Agra district**

than 1.25 which indicates the groundwater quality as *Excellent Class* type.

CONCLUSIONS

The groundwater quality of various blocks of Agra district is characterized as $Naz - Cl^-$, $Ca^{2+}- Na^+ -HCO_3^-$, $Ca^{2+} - Mg^{2+} - Cl^-$, $Ca^{2+} - HCO_3^-$, $Ca^{2+} - Cl^-$, $Na^+ - Cl^-$, $Ca^{2+} - Mg^{2+} - Cl^- - SO_4^{2-}$, $Ca^{2-} - Naz - HCO_3^-$ type. It is also concluded that the quality of water for the block Barauli Ahir, Fatehapur Sikari, Saiyan, Achhnera, Shamsabad, Khandouli, Pinahat, Jaitpur Kalan and Bah falls under *Medium to Very Good* category and can be used for the irrigation purpose. However, the quality of water for the blocks Bichpuri, Akola, Fatehabad, Khairagarh, Etmadpur and Jagner falls under *Medium to Very Bad* category and hence must be used with caution for the irrigation purpose depending on the soil types and salinity resistant crops.

ACKNOWLEDGEMENTS

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