# Groundwater Quality Assessment with Special Reference to Irrigation Purpose, Chhindwara Block, District-Chhindwara, Madhya Pradesh

**Mohd. Maroof Khan[1] Dr. H.U. Usmani[2]**
[1,2]Department of Geology
[1,2]Govt. Motilal Vigyan Mahavidhyalaya, Bhopal

*Abstract*— A study is conducted to assess the groundwater quality of the Chhindwara block, Distt. Chhindwara. Specifically, the irrigation water quality is to be determined. The parameters for determining the irrigation water quality are soluble sodium percentage, sodium absorption ratio, Kelley's ratio, Permeability index, magnesium ratio and residual sodium carbonate. The calculated sodium absorption values of the groundwater samples of the study area suggested that the water is excellent for irrigation purpose. The other parameters also suggest that the groundwater is suitable for irrigation. The samples plotted on U.S. salinity diagram indicate that the groundwater of the region is medium to high saline and low alkaline in nature.
***Key words:*** Chhindwara, Groundwater, Sodium absorption ratio, Granites

## I. INTRODUCTION

In order to establish the suitability of groundwater for different purposes, it is essential to analyze its physical, chemical and biological characteristics which are helpful in ascertaining its quality. Present day industrialization and technological advancement have adversely affected our natural resources; specially the water resources. As industrial, agricultural and sewage wastes are being mixed with hydrological cycle causing pollution of water resources. Consumption of this polluted water has become a root cause of ill health of the people consuming it. Along with the human effects, it also affects the growth of plants and highly dangerous for irrigation. Hence, quality study of water resources has become a matter of concern. Looking to the need of quality assessment, the hydrochemical study of the groundwater of the present area has been carried out.

## II. CHHINDWARA BLOCK

Present study area is part of Chhindwara district of M.P. which falls on SOI toposheet no.55 N/4 which is bounded between latitudes $22^0$05' to $22^0$10' North and longitude $77^0$10' to $77^0$20' East. The fluoride as a contaminant has been reported from various villages of the Chhindwara district, by the workers of Central Ground Water Board and PHED of Govt. of M.P. In most of the places, the study area is covered by black cotton soil which is highly good for irrigation purpose. Fluoride is also a problem in that area. Fluoride as contaminant is not safe to consume as drinking water as it causes several health hazards. It is a common pollutant of groundwater in shallow as well as deep aquifers, where it reaches by dissolution of either the fluoride containing minerals or from other sources, fluoride in various parts of study area will be assessed and their possible sources will be delineated.

## III. GEOLOGY

A variety of rocks are exposed in the Chhindwara block that span in age from the Precambrian to Recent. The principal features of the area are after all a reflection of geology and the structures of the region. The high mountainous country of the north owes its majestic heights to Gondwana sandstones and the Deccan trap hills, while the plateau between Khirsadoh and Chhindwara town forms a rolling country of granites and occasional gneisses whose monotony is broken by the reticulating ridges of the trap hills. The rock formations exposed in the area mainly consist of pink to grey granites, migmatites and unclassified gneisses of Archaean age overlained by the basic volcanic rocks of Deccan trap activity which belong to Cretaceous to Eocene age. These Archaean rock formations belong to Sausar Group. There are various metasediments also present with the rocks of Sausar group, whereas in the present study area, these metasediments are not exposed except the granitic rocks. These granitic rocks include the grey granites along with porphyroblastic granite gneisses, pink granites and apalite with pegmatite and quartz vein and porphyroblastic granites (Augen gneiss, Fig 1).

Fig. 1: Porphyroblastic granite

These granitic rocks occur as inlier in the area surrounded by the rock of Gondwana Supergroup in the north and by the Deccan Trap flows in the south andeastern part. The total area covered by the Precambrian granites is about 154 sq. km. Most of it is occupied by pink granites and its associates, the porphyroblastic granites, the grey granites and granites gneisses. Several xenoliths of the country rocks are seen in the pink granites.

 

Fig. 2: Basaltic rock having vertical and inclined joints

The basaltic lava flows of Upper Cretaceous to Eocene age are also found in the area which belongs to Amarkantak group. More than 10 lava flows have been reported in this region. These flows comprises of four basaltic flows of simple and compound type. The rock of these flows are hard and compact, moderate to high porphyritic, fined to medium grained, dominantly consist of calcic plagioclase and pyroxene along with glassy groundmass. The major part of the study area is covered by the basaltic rocks of Linga formation. These rocks are also jointed several sets of vertical and inclined joints are observable in these rocks (Fig 2). In most of the places, these lava flows are exposed whereas in some places, these flows are covered either by thick or thin layers of soil.

## IV. IRRIGATION WATER QUALITY

### *A. Soluble Sodium Percentage (SSP):*

Sodium is important in classifying irrigation water, because sodium reacts with soil thereby reducing the permeability. Percent sodium in water is a parameter computed to evaluate the suitability of water quality for irrigation (Wilcox 1948). The %Na is computed with respect to relative proportions of cations present in water, where the concentrations are expressed in meq/l using the formula. It is an important parameter to classify the groundwater samples for irrigation purpose. It is calculated by the formula proposed by Doneen (1962) as under;

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

Sodium along with carbonate forms alkaline soil; while sodium with chloride forms saline soil; both of these are not suitable for the growth of plants (Pandian and Shankar, 2007). The quality classification of irrigation water based on the values of sodium percentage is proposed by Wilcox (1955).

### *B. Sodium Absorption Ratio (SAR):*

Sodium in irrigation water can adversely affect the soil beneath the plant canopy. The water quality parameter known as the Sodium Adsorption Ratio, or SAR, is useful when assessing the likelihood that sodium will be a problem in that regard. Sodium adsorption ratio (SAR) is a measure of the suitability of water for use in agricultural irrigation, as determined by the concentrations of solids dissolved in the water. It is also a measure of the sodicity of soil, as determined from analysis of water extracted from the soil.

The formula for calculating sodium adsorption ratio is:

$$\text{S.A.R.} = \frac{Na^+}{\sqrt{\frac{1}{2}(Ca^{2+} + Mg^{2+})}}$$

Where sodium, calcium, and magnesium are in milli equivalent/liter.

Although SAR is only one factor in determining the suitability of water for irrigation, in general, the higher the sodium adsorption ratio, the less suitable the water is for irrigation. Irrigation using water with high sodium adsorption ratio may require soil amendments to prevent long-term damage to the soil.

As per classification of Wilcox (1955), water with SAR ≤10 is considered as an excellent quality, between 10 to 18 is good; between 18 to 26 is fair and greater than 26 is said to be unsuitable for irrigation purpose in its natural form. The values of SAR for all the groundwater samples of the study area are less than 10; hence the water of the study area is excellent for irrigation purpose.

### *C. Kelley's Ratio (KR):*

It is the ratio of sodium ion to calcium and magnesium ion in epm (Kelley, 1951) and expressed as;

$$\text{K.R.} = \frac{Na^+}{Ca^{+2} + Mg^{+2}} \text{ (epm)}$$

The Kelley's Ratio (KR) have been computed for all groundwater samples of the study area. In the study area KR ranges from 0.035 to 2.406 indicating that water is suitable for irrigation purpose as most of the values of Kelley' ratio is less than 1.

### *D. Permeability Index (PI):*

The classification of irrigation waters has been attempted on the basis of permeability Index, as suggested by Doneen (1962). The soil permeability is affected by long term use of irrigation water as it influenced by sodium, calcium, magnesium, and bicarbonate content of the soil. Doneen (1964), WHO (1989) gave a criterion for assessing the suitability of groundwater for irrigation based on the permeability index (PI), where concentrations are in meq/l.

$$PI = \frac{(Na^+ + \sqrt{HCO3^-})}{(Ca^{+2} + Mg^{+2} + Na^+)} \times 100$$

Accordingly, the permeability index is classified under class 1 (>75%), class 11(25-75%) and class 111(<75%) orders. Class 1 and class 11 waters are categorized as good for irrigation with 75% or more of maximum permeability. Class 111 waters are unsuitable with 25% of maximum of maximum permeability. The groundwater samples of the study area fall in class-I.

### *E. Magnesium Ratio (MR):*

Generally calcium and magnesium maintain a state of equilibrium in groundwater. More magnesium present in waters affects the soil quality converting it to alkaline and decreases crop yield. Szabolcs and Darab (1964) proposed magnesium hazard (MH) value for irrigation water as given

$$MR = \frac{(Mg^{+2})}{(Ca^{+2} + Mg^{+2})} \times 100$$

Where the concentrations in meq/l.

If the Magnesium Ratio is greater than 50 %, it is considered as suitable for irrigation purpose (Palliwal, 1972). In the present study area, the values of magnesium ratio varies from 9.92% to 51.20%, whereas there is only one sample whose MR value is slightly more than 50% whereas all the samples have magnesium ratio less than

50%. So the groundwater of the study area is good for irrigation.

### *F. Residual Sodium Carbonate (RSC):*

The residual sodium carbonate (RSC) equals the sum of the bicarbonate and carbonate ion concentrations minus the sum of the calcium and magnesium ion concentrations, where the ions are expressed in meq/l. A negative RSC indicates that sodium buildup is unlikely since sufficient calcium and magnesium are in excess of what can be precipitated as carbonates. A positive RSC indicates that sodium buildup in the soil is possible. The degree of sodium hazard is as shown in the Table below:

| | HAZARD |
|---|---|
| <0 | None. |
| 0-1.25 | Low, with some removal of calcium and magnesium from irrigation water. |
| 1.25-2.50 | Medium, with appreciable removal of calcium and magnesium from irrigation water. |
| >2.50 | High, with most calcium and magnesium removed leaving sodium to accumulate. |

Table 1: Degree of sodium hazard

Residual sodium carbonate (RSC) index of irrigation water or soil water is used to indicate the alkalinity hazard for soil. The RSC index is used to find the suitability of the water for irrigation in clay soils which have a high cation exchange capacity. When dissolved sodium in comparison with dissolved calcium and magnesium is high in water, clay soil swells or under goes dispersion which drastically reduces its infiltration capacity.

In the dispersed soil structure, the plant roots are unable to spread deeper into the soil due to lack of moisture. However, high RSC index water does not enhance the osmotic pressure to impede the off take of water by the plant roots unlike high salinity water. Clay soils irrigation with high RSC index water leads to fallow alkali soils formation.

The RSC values > 1.25 mg/l are considered as safe for irrigation while those from 1.25 mg/l to 2.5mg/l are marginally suitable for irrigation. If RSC values are > 2.5 the groundwater is unsuitable for irrigation (Eaton, 1950; Richards, 1954). The formula for calculating RSC index is:

$$RSC\ index = [HCO_3 + CO_3] - [Ca + Mg]$$

The RSC values of groundwater samples of the study area ranges from -13.04 to +7.75 mg/l and the average value of Residual sodium carbonate (RSC) for the water samples is 4.09. This high value of RSC indicates that the soil of the study area have higher amount of dissolved sodium in comparison to the dissolved calcium and magnesium which results in swelling and dispersion in soil and reduced its infiltration capacity.

## V. DISCUSSION

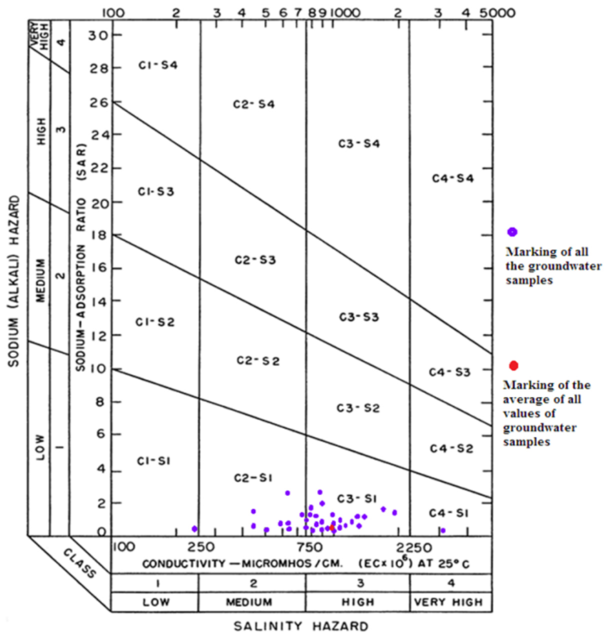


Fig. 3: Diagram for classification of irrigation waters describing 16 classes

The US Salinity Laboratory has proposed a diagram for classification of irrigation waters describing 16 classes, with reference to SAR as an index for sodium hazard and EC as an index of salinity hazard. The sixteen classes in the diagram indicate the extent that the waters can affect the soil in terms of salinity hazard. These classes are: low salinity (C1), medium (C2), high (C3) and very high salinity (C4) and similarly sodium hazard as low (S1), medium (S2), high (S3) and very high (S4). When the groundwater samples are plotted in the US Salinity Diagram (Fig 3), then most of the samples of the study area come under the field/class $C_3$-$S_1$ which reveals that the water of these 30 samples belongs to medium – high salinity and low sodium, which is good for irrigation.

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