

A NEW DIAGRAM FOR CLASSIFICATION OF NATURAL WATERS AND  
INTERPRETATION OF CHEMICAL ANALYSES DATA

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ABSTRACT

Various graphic methods are in vogue for study and interpretation of water quality data. However, it is a paradox that none of the methods gives a specific classification of waters. The prevalent trilinear diagram of Hill-Piper can be effectively used for geochemical study of water but it has limitations in classifying different types of waters. In the paper, a modified diagram has been proposed which can be utilized for (1) classification of natural waters (2) geochemical study of waters like base exchange, sulphate reduction, mixing etc. and (3) to find suitability of water for irrigation purpose. The proposed diagram is a modification of Hill-Piper diagram, with a view to extending its applicability in representing water analyses data efficiently. To illustrate the applicability of the diagram two case histories are discussed.

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INTRODUCTION

A number of graphical methods are in vogue for representing the chemical quality data of natural waters. Amongst these the trilinear plotting system has won popularity. Hill-Piper diagram has been widely used to study the similarities and differences in the composition of waters and to classify them into certain chemical types. However, the classification of water by this diagram is not specific. The nine types of waters given by Piper (ref. 1) show the essential chemical character of water rather than grouping them into different classes. Further, there are effectively only 5 classes. The classes from 1 to 4 are but repetitions of other classes though in broader groups.

Also in Piper's diagram only the relative concentration of the different constituents in percentage reacting values, expressed in milligram equivalent, is represented. As absolute concentrations are commonly decisive in many problems of interpretation, Piper suggested the method of encircling the plotting in central diamond field, with its area proportional to the absolute concentration. This method is not very convenient when plotting of a large volume of data is involved. The above mentioned shortcomings do not lessen the usefulness of Piper's diagram, specially in the study of mixing of waters, modifications in chemical character of waters and related geochemical problems. Necessity is however, felt to combine the qualities of this diagram with an improvement in the method of classification of waters. An attempt has been made in this direction by presenting a diagram which can be effectively used for a suitable classification of natural waters as also to study their geochemical behaviour and suitability for irrigation purposes.

#### PROPOSED DIAGRAM

The proposed diagram (Fig. 1) is a modification of the Hill-Piper diagram. The difference being in the shape of the three fields of study. Instead of equilateral triangles, right angled isosceles triangles have been used for plotting cations and anions. The advantage is that the resulting central field is square, instead of diamond shaped. One side of the square represents percent sodium and hence the diagram can easily be supplemented with the Wilcox's percent sodium diagram, thus expanding the scope of study. Also the plotting in right angled triangles is comparatively easier.

The two right angled triangles, one for cations and other for anions, are essentially used for classification of waters. The three sides of each triangle, divided into 100 equal parts, represent the percentage reacting values of cation and anion groups. The cation and anion triangles are subdivided into 7 fields each, giving the following types of waters :

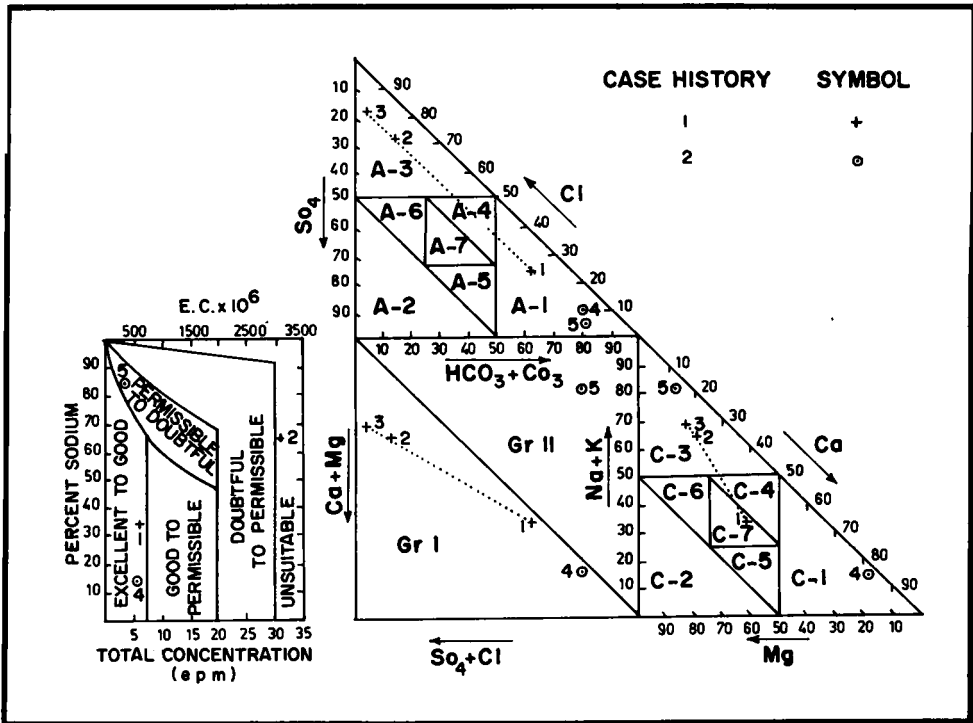


Fig. 1. Proposed Diagram for geochemical studies of waters.

**Cation Triangle.**

- C<sub>1</sub> - Calcium type
- C<sub>2</sub> - Magnesium type
- C<sub>3</sub> - Sodium type
- C<sub>4</sub> - Sodium-Calcium type
- C<sub>5</sub> - Calcium-Magnesium type
- C<sub>6</sub> - Sodium-Magnesium type
- C<sub>7</sub> - Calcium-Magnesium-Sodium type

**Anion triangle.**

- A<sub>1</sub> - Bicarbonate type
- A<sub>2</sub> - Sulphate type
- A<sub>3</sub> - Chloride type
- A<sub>4</sub> - Chloride-Bicarbonate type

- A<sub>5</sub> - Bicarbonate-Sulphate type
- A<sub>6</sub> - Chloride-Sulphate type
- A<sub>7</sub> - Bicarbonate-Sulphate-Chloride type

The proportion of the principal cation and anion, in terms of percentage reacting values, are plotted in each triangle and the type of water found out, on the basis of the position of plotting in respective field. For example a water falling in C<sub>1</sub> and A<sub>2</sub> fields of cation and anion triangles can be classed as Calcium-Sulphate type of water.

The Central square field gives the overall character of water. It has all the advantages of the diamond shaped field of Piper's diagram and can be used to study the mixing character of waters, the changes in the chemical characters and other related geochemical problems. For representing the primary character of water, the square field has been sub-divided into two. The waters falling in Group I will have alkaline earths (Ca, Mg) exceeding the bicarbonates. Such water will show permanent hardness and will not have bicarbonate hazard for irrigation. On the other hand, the water of Group II will have temporary hardness and have residual sodium carbonate.

The plotting in the square field can be extended into Wilcox's diagram. Thus, in addition to finding the suitability of water for irrigation purposes, the salinity of water can also be known, facilitating a more comprehensive understanding.

#### CASE HISTORIES ILLUSTRATING THE APPLICABILITY OF THE PROPOSED DIAGRAM

##### Case History 1 :

Chemical quality of groundwater in Dharangadhra sandstones of Upper Jurassic to Lower Cretaceous age, exposed in parts of Surendranagar district of Gujarat, India, presented a problem of wide variation in the quality of groundwater both areally and with depth. The mechanism of this variation could be better understood by plotting in the recommended diagram, the chemical analyses data of waters collected

from different depths, during exploratory drilling. Drilling at 16 sites down to depth range of 145 to 300 metres below surface, revealed two major groups of sandstone aquifers, separated by 4 to 10 m thick carbonaceous arenaceous shales, occurring persistently at depths ranging from 50 to 180 m b.g.l. A thick basic sill (30 to 50 m) was also encountered below the carbonaceous shale in northern parts, with limited areal extent. Groundwater in the aquifers below the carbonaceous shale/sill was found to be under artesian head.

During exploration, samples of water were collected from aquifers overlying and underlying the basic sill and from different depths from other parts of the area where the sill was not encountered. It was observed that in the area where the basic sill occurs, Sodium-Bicarbonate type of water extends down to the basic sill. An abrupt deterioration in quality (NaCl type) was noticed in water samples collected from aquifers underlying the basic sill. However, in other areas where basic sill does not occur, the quality of groundwater shows a gradual deterioration. The plots in the recommended diagram (Fig. 1) for waters from phreatic aquifer and aquifers overlying and underlying the carbonaceous shale, collected from a borehole, fall on a straight line in all the three fields of study, indicating the mixing character of water.

It was concluded that the saline water of NaCl type in the aquifers below the carbonaceous shale, moves upward due to the positive head and the semi-pervious nature of the aquiclude and mixes with the generally Calcium-Bicarbonate type of water in the shallow aquifers, to give rise to a mixed water zone of diluted NaCl to Na-Ca-HCO<sub>3</sub> type. However, in the northern parts of the area, where the impervious basic sill occurs, the quality of groundwater is good down to the sill because it acts as an impermeable barrier and prevents upward movement of saline water.

#### Case History 2 :

An area of about 11,500 sq.km. in Upper Yamuna Basin, (Haryana and Uttar Pradesh States of India) forming a part of the Indo-Gangetic

alluvia of Quaternary age, was studied. The analytical data of waters from different depths at locations widely spread over the basin were plotted in the recommended diagram. It was observed that Calcium-Bicarbonate type of water occurs in the phreatic aquifers. This water gradually deteriorates to Sodium-Bicarbonate type with depth, rendering the 'good to excellent' category of water into 'permissible to doubtful' for irrigation uses. The plots in the square field of study (Fig. 1) show an increase of the percentage of Na + K at the cost of Ca + Mg indicating a base exchange between the cations of Calcium-Bicarbonate type of water and the sub-surface clays. The thickness of alluvium in this area exceeds 500 metres and only a small fraction of this is under active circulation due to groundwater development. The under utilization of groundwater from deeper aquifers results in a near stagnant condition at depths and provide the necessary time factor for base exchange. There is thus a strong case for the development of deeper aquifers.

#### CONCLUSIONS

From the foregoing discussions it is apparent that the recommended diagram helps in a better understanding of water quality data. It satisfies the basic requirement for a suitable classification of natural waters and can be effectively used in the geochemical studies, in addition to giving an idea on the suitability of water for irrigation purpose.

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#### REFERENCE

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