Graphic Interpretation and Assessment of Water Quality in the Savitri River Basin.

P. B. Lokhande, H. A. Mujawar

Abstract: The physical and chemical parameters of surface water play a significant role in classifying and assessing water quality. In this study, analysis of water from Savitri river was carried out for six locations during monsoon, winter and summer season from June 2006 to May 2007. Cation and anion concentrations in water samples at different locations were determined by using Ion-Chromatography and represented by using Stiff, Piper, Durov, Schoeller, Wilcox, USSL diagram. The presentation of chemical analysis in graphical form makes understanding of complex surface water system too simpler and quicker. Percentage of Na, SAR, RSC, Sodium hazard and exchangeable sodium ratio values indicates the unsuitability of river water for irrigation and drinking purposes.

Key words: Durov, Stiff , Piper diagram. SAR, RSC, Wilcox diagram.

1.Introduction: -

Pollution of surface water with toxic chemicals and eutrophication of rivers and lakes with excess nutrients are of great environmental concerned wordwide. Agricultural, industrial and urban activities are considered as being major sources of chemicals and nutrients to aquatic ecosystems [15]. Physical and chemical parameters of surface water play a significant role in classifying and assessing water qualify. Considering the individual of paired ionic concentration, certain indices to find out the alkali hazards were proposed [14]. [9].

It was observed that the criteria used in the classification of waters for a particular purpose may not find the suitability standard for other purposes, and better results can be obtain only by considering the combined chemistry of all the ions rather than individual or paired ionic characters. Chemical classification also throws light on the concentration of various predominant cations, anions and their interrelationships. Presentation of chemical analysis in graphical form makes understanding of complex water system simpler and quicker. A number techniques and methods have been developed to interpret the chemical data [15].

Methods of representing the chemistry of water like Piper diagram, stiff diagram, Wilcox diagram, Durov diagram, Schoeller have been used in many parts of the world to show the proportion of ionic concentration in individual samples. Balasubramanian [3] and Subramanian followed a series of methods to interpret and classify the chemistry of ground water in hard rock, including coastal zones in the southern part of India. Zaprozec [27] summarized the various modes of data representation and discussed their possible uses.

ISSN 2229-5518

The objective of the present work is to discuss the ion chemistry of Savitri river water in this case the methods proposed by Piper [20], Wilcox [25], Back and Hanshaw [4], Eaton, Stiff [21] and USSL classifications have been used to study the critically the geo-chemical characteristic of the Savitri river water. It is an attempt to apply these methods to compare the assessment data of the river system also.

2. Materials and Methods:

2.1 Study area:

The Savitri river basin is located near to the Mahad of Konkan region in India at 18^0 05′ and 73^0 25′ East. Mahad industrial area lies on the right bank of Savitri river. Savitri river is one of the major river in Konkan region. It starts at Mahabaleshwer, flows through hilly area and emerged into Arabian sea which is 40 km away from the Mahad. Kal river, Gandhari river and one water stream which flows through the Mahad industrial area joins to Savitri river. Sewage of Mahad city is also discharged into the river. Pharmaceutical, pesticide dye intermediates and drug industries are located in Mahad industrial area that discharges large quantities of waste water in river hence pollute the river.

2.2 Sample collection:

Samples were collected during the monsoon, winter and summer seasons of June 2005 to May 2006 from Savitri river and one stream that flows through industrial area and joins rivers. Out of total six sampling sites, three sites are in the industrial area and three are after the MIDC area. I^{st} sampling site was selected from the central part of industrial area, II^{nd} was from the confluence of industrial stream and Kal river, III^{rd} sample was taken from the confluence of Kal river and Savitri river, IV^{th} sample from Gandhari river, V^{th} from after the Mahad city and last VI^{th} from near the Dasgaon village where sea water inter in river basin. All samples were collected in pre-cleaned HDPE sample container of having 2000 ml capacity. The sample containers were completely filed to eliminate any headspace and dissolution of oxygen from air. Before to collect the samples bottles were rinsed with sample water. After sample collection, the containers were labeled wrapped with Para film and stored in ice for transport. All samples were stored in laboratory in their original container at 4 ^{0}C.

2.3 Analysis of river water:

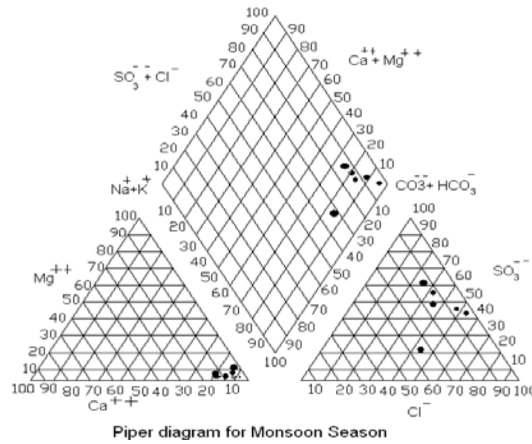
The physico-chemical analysis of water quality parameters was carried out by following standard

ISSN 2229-5518

methods by APHA (1992) [1]. Cation and Anion analysis were done on Ion chromatograph instruments (Metrohm make). Eluents used for anion 3.2 m M Na_2CO_3 / 1 m M $NaHCO_3$, flow rate 0.7 ml /min, pressure 10.6 m Pa and for anion column used metrosep C2 – 250, Eluents- 4 m mol / L Tartaric acid / 0.75 m mol / L dipicolinic acid, Flow rate 1 ml/ Min and pressure 10.1 m Pa. RockWare Aq.Qa software was used to draw the figure and to calculate the conversion.

3. Results and discussion:

The Piper-Hill diagram [20] is used to infer hydrogeo-chemical facies. These plots include two triangles, one for plotting cations and the other for plotting anions. The cation and anion fields are combined to show a single point in a diamond-shaped field, from which inference is drawn on the basis of hydrogeo-chemical facies concept [4]. These tri-linear diagrams are useful in bringing out chemical relationships among groundwater samples in more definite terms rather than with other possible plotting methods [24].



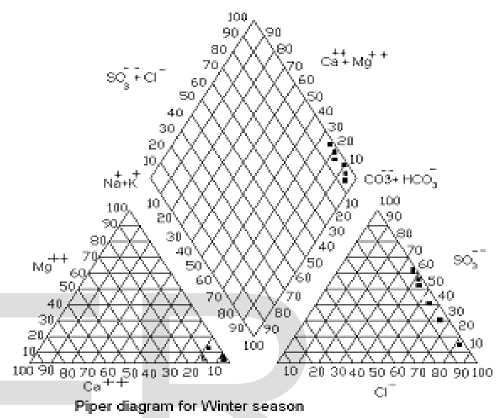
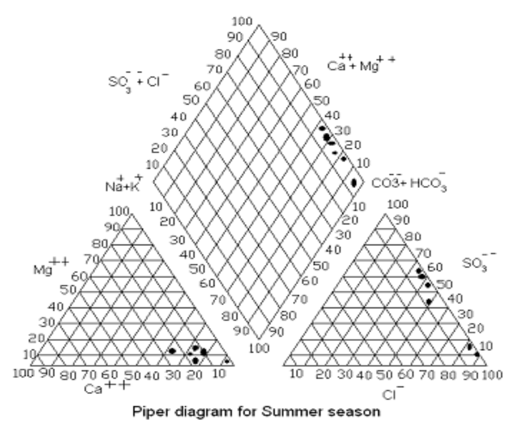


Fig. 1 (A). Piper Tri-linear diagram for Monsoon, winter and summer season



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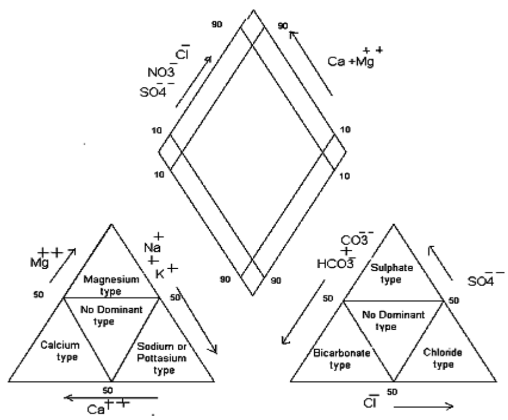

Fig. 1(B) Piper Tri-linear diagram for Monsoon, winter and summer season.

Chemical data of the study are presented by plotting them on a Piper tri-linear diagram for each season (Fig. 1 a and B). The concept of hydro-chemical facies was developed in order to understand and identify the water composition in different classes [4],[5]. Facies are recognizable parts of different characters belonging to any genetically related system. Hydro-chemical facies are distinct zones that possess cation and anion concentration categories. To define a composition class, Back and co-workers [4] suggested subdivisions of the tri-linear diagram (Figure 1 B). The interpretation of distinct facies from the 0 to 10% and 90 to 100% domains on the diamond-shaped cation to anion graph is more helpful than using equal 25% increments. It clearly explains the variation or domination of cation and anion concentrations during each season. Na-type of water predominated in all the six study areas and for all three season. Sulphate types of samples for monsoon are two, for winter and summer three samples. Only one sample is chloride type during monsoon, three samples in winter and two samples in summer. It is observed that the effect of carbonate is very less and negligible for all the three seasons.

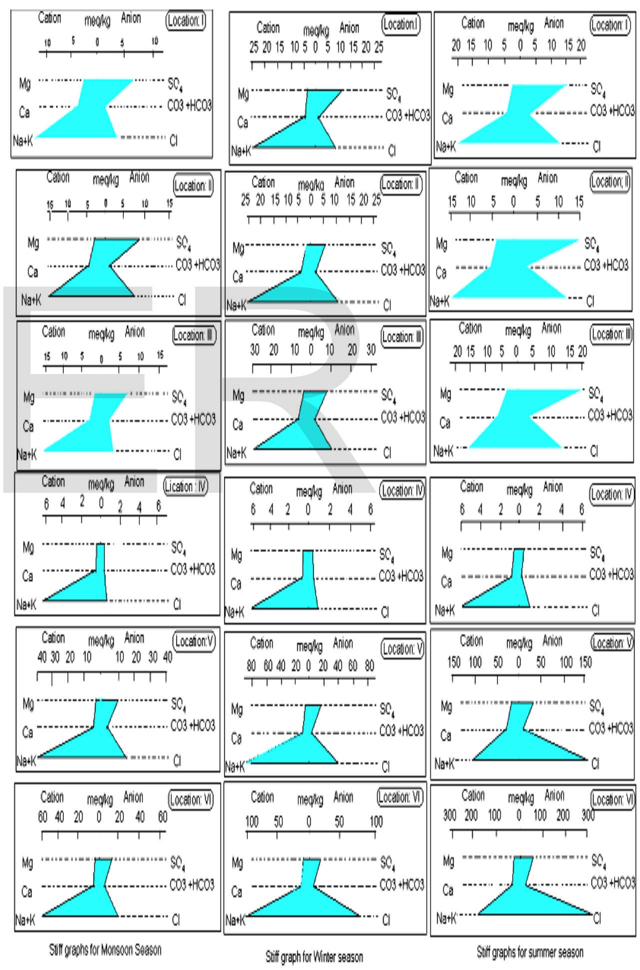

Fig 2. Stiff diagram of cation and anion concentration for different sampling stations

ISSN 2229-5518

Stiff diagrams are commonly used visual method to directly compare the relative concentration of dissolved cations and anions based on sample location. Fig. 2 uses a variation of Stiff diagram for Monsoon, Winter and Summer season to compare mean concentrations of the major dissolved ions (Na, K, Cl, Ca, Mg, SO4, CO3 and HCO3) at each sample site. Stiff diagrams (Fig. 2 A,B) shows that there is a variation in the concentrations of Ca, Mg, Na, Cl, SO4 among the six sites in this study. However, the stiff diagrams clearly demonstrate the mean concentrations of cations and anions increased substantially as from monsoon to summer season.

The suitability of groundwater for irrigation purposes depends upon its mineral constituents. The general criteria for judging the quality are:(i) total salt concentration as measured by electrical conductivity (EL). (ii) Relative proportion of sodium to other principal cations as expressed by SAR, (iii) Bicarbonate (HCO^-_3) and (iv) Boron.

Wilcox classified groundwater for irrigation purposes based on percent sodium and EC. Eaton [9] recommended the concentration of residual sodium carbonate to determine the suitability of water for irrigation purposes. The US Salinity Laboratory of the Department of Agriculture adopted certain techniques based on which the suitability of water for agriculture is explained.

Table. 1. Seasonal chemical character for each sampling location.

Season	Chemical Character	Sampling locations of Savitri river					
		I	II	III	IV	V	VI
Monsoon	SAR	8.06	10.1	11	11	23.8	35.9
	ESR	2.72	3.07	3.79	11.93	7.02	10.35
	RSC	-3.31	-3.63	-2.5	-.256	-3.79	-3.75
	%Na	69.6	73.4	75.9	91.2	83.9	88.4
Winter	SAR	12.2	14.5	15.2	10.7	38.9	38.4
	ESR	3.77	4.6	5.01	9.42	10.06	7.73
	RSC	-3.88	-3.2	- 3.18	- 0.374	-5.09	-9.48
	%Na	72.8	76.8	77.9	82.6	88.1	85.8
Summer	SAR	9.25	6.95	7.4	10.7	19.7	27.2
	ESR	2.6	1.68	1.91	9.4	2.47	3.12
	RSC	-4.49	-6.78	- 2.99	- 0.587	- 26.46	- 31.56
	%Na	65.3	57.13	61.1	82.2	69	74

(SAR- Sodium adsorption ratio, ESR- Exchangeable sodium ratio, RSC- Residual sodium carbonate)

ISSN 2229-5518

Exchangeable Sodium ratio values are higher for winter seasons at all the locations except location VI shows higher ESR value for monsoon season. Exchangeable Sodium ratio (ESR) is calculated as follows

$$ESR = [Na^{+}] / [Ca^{2+}] + [Mg^{2+}]$$

Where concentrations are in unit of meq/L

The sodium in irrigation water is usually denoted as per cent sodium and can be determined using the following formula

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

Where the quantities of Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} are expressed in milliequivalents per litre (epm).

The classification of groundwater samples with respect to percent sodium and EC is shown in Figure 3. It is observed that 50% samples lies in excellent to good, 27.7% lies in good to permissible, 11% in doubtful to unsuitable and 11% in unsuitable. Water from Sampling location V and VI is unsuitable for irrigation.

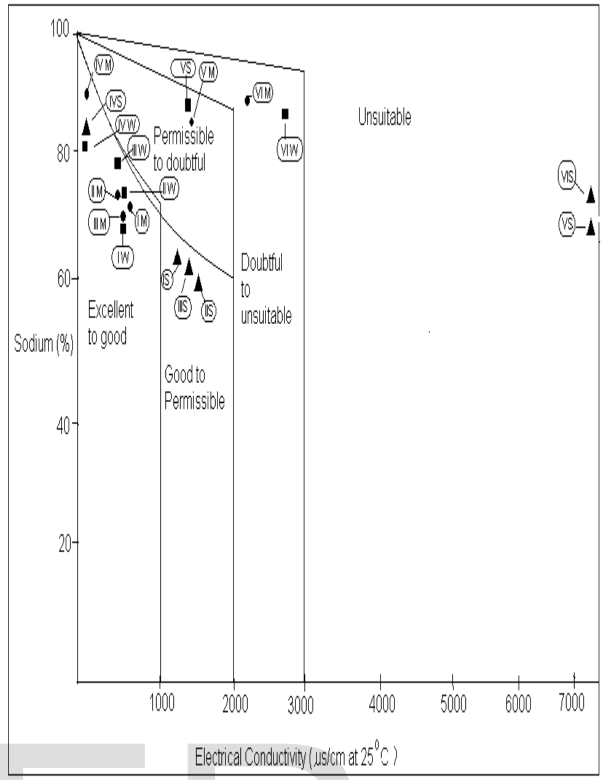

Fig. 3 Wilcox diagram of river water for Monsoon, winter and summer season.

(Roman letter indicates sampling stations and M-Monsoon, W-Winter and S-Summer.)

In waters having high concentration of bicarbonate, there is a tendency for calcium and magnesium to precipitate as the water in the soil becomes more concentrated. As a result, the relative proportion of sodium in the water is increased in the form of sodium carbonate. RSC is calculated using the following equation.

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

Where all ionic concentrations are expressed in epm.

ISSN 2229-5518

According to the US Department of Agriculture, water having more than 2.5 epm of RSC is not suitable for irrigation purposes. RSC values for all samples and each season were calculated and shown in table 1. All values obtained are negative and less than 2.5 epm.

The most important characteristics of irrigation water in determining its quality are: (i) Total concentration of soluble salts; (ii) Relative proportion of sodium to other principle cations; (iii) Concentration of boron or other elements that may be toxic and (iv) Under some conditions, bicarbonate concentration as related to the concentration of calcium plus magnesium.

These have been termed as the salinity hazard, sodium (alkali) hazard, boron hazard and bicarbonate hazard. For the purpose of diagnosis and classification, the total concentration of soluble salts (salinity hazard) in irrigation water can be expressed in terms of specific conductance. In the past, the sodium hazard has been expressed as per cent sodium of total cations. A better measure of the sodium hazard for irrigation is the SAR, which is used to express reactions with the soil. SAR is computed as:

$$SAR = \frac{Na^{+}}{[\,Ca^{2+} + Mg^{2+}\,]^{1/2}}$$

Where all ionic concentrations are expressed in epm .

The classification of groundwater samples from the study areas with respect to SAR is represented in Table 1. SAR values of the site V and VI for the all three seasons were found to be very high and classified not suitable for irrigation. During the summer season SAR values of site I, II and III were found to be less than 10.

When the SAR and specific conductance of water are known, the classification of the water for irrigation can be determined by graphically plotting these values on the US salinity (USSL) diagrams. Waters have been divided into C1, C2 C3 and C4 types on the basis of salinity hazard and S1, S2, S3, S4 types on the basis of sodium hazard. The significance and interpretations of quality ratings on the USSL diagram can be summarized as follows: (i) Low salinity water (C1) can be used for irrigation with most crops on most soils. Some leaching is required, but this occurs under normal irrigation practices, except in soils of extremely low permeability. (ii) Medium salinity water

(C2) can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most instances without special practices of salinity control. (iii) Medium to high salinity water (C3) is satisfactory for plants having moderate salt tolerance, on soils of moderate permeability with leaching. (iv) High salinity water (C4) cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity may be required and plants with good salt tolerance should be selected. (v) Very high salinity water (C5) is not suitable for irrigation under ordinary conditions, but may be used occasionally, under very special circumstances. The soil must be permeable, drainage must be adequate, irrigation water must be in excess to provide considerable leaching and salt tolerant crops should be selected.

The classification of irrigation waters with respect to SAR is based primarily on the soil. Sodium-sensitive plants may, however, suffer injury as a result of sodium accumulation in the plant tissue when exchangeable sodium accumulation in the physical condition of the soil. Sodium-sensitive plants may, however, suffer injury as a result of sodium accumulation in the plant tissue when exchangeable sodium values are lower than those effective in causing deterioration of the physical condition of the soil.

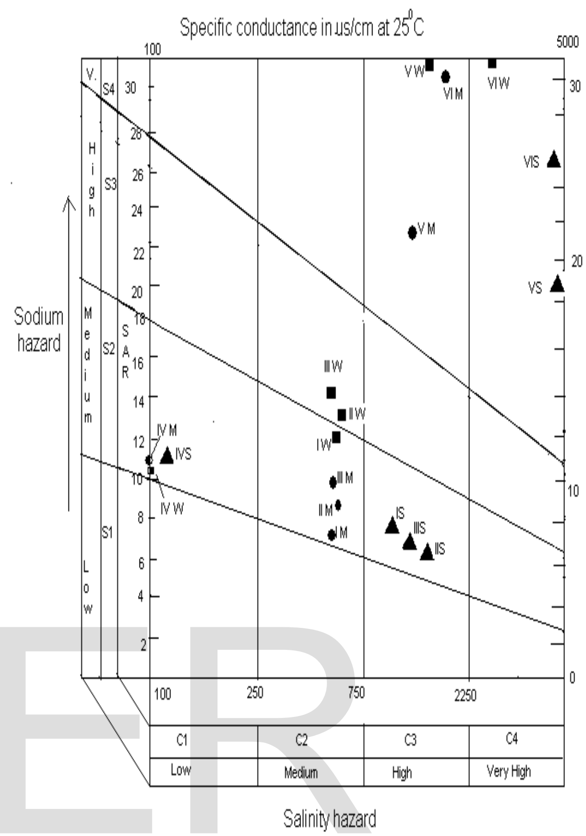

Fig. 4. USSL classification of river water for Monsoon, winter and summer season.

Low sodium water (S1) can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. However, sodium sensitive crops, such as stone-fruit trees and avocados may accumulate injurious concentration of sodium [2].

Medium sodium water (S2) in fine-textured soils of high cation exchange capacity, especially under low

ISSN 2229-5518

leaching conditions, unless gypsum is present in the soil, presents appreciable sodium hazard, but may be used on coarse textured or organic soils, which have good permeability.

Very high sodium water (S4) is generally unsatisfactory for irrigation purposes, except at low and perhaps medium salinity. Application of gypsum or other amendments may render this water feasible. Application of gypsum also increases the crust conductivity property of the soil.

The plots of groundwater chemistry of study areas in the USSL diagram are shown in Figure 4. Sampling sites lies in the S4-C4 group are VIW, VIS, VS and S4-C3 group are VW, VIM, VM shows high salinity hazard and sodium hazard. Sampling site IS, IIS, IIIS lies in S2-C3 type having high salinity hazard and medium sodium hazard. Whereas others are comes under the category of medium to low salinity and sodium hazard.

The suitability of water for irrigation was evaluated based on SAR, % Na, RSC and USSL diagrams. Taking into account all these criteria, one can best evaluate the suitability of water for irrigation purposes, rather than by considering a specific criterion, because water satisfying all the criteria is rare. As the study areas are in the vicinity of industrial area and also affect by the tide, where the water is NaC1-type, SAR and %Na are above the permissible limits for irrigation purposes, whereas RSC is well below the guideline values.

The USSL diagram best explains the combined effect of sodium hazard and salinity hazard. According to this, most of the groundwater in these areas falls in C3S3 and C4S4 type and hence is unsuitable for irrigation. Similar conclusions are drawn from the Wilcox diagram by plotting percent sodium against EC.

Though the suitability of water for irrigation is determined based on SAR, %Na, RSC and USSL diagram, it is only an empirical conclusion. In addition to water quality, other factors like organic contents, soil type, crop pattern, frequency and recharge (rainfall), climate, etc. have an important role in determining the suitability of water. Hence water that is not suitable based on the above classification may be suitable in well-drained soils.

4. Conclusion:

Analysis of water from Savitri river was carried out for six locations during monsoon, winter and summer season from June 2006 to May 2007. Na-type of water predominated in all the six study areas and for all three season. The stiff diagrams clearly demonstrate the mean concentrations of cations and anions increased substantially as from monsoon to summer season. The suitability of water for irrigation was evaluated based on SAR, % Na, RSC and USSL diagrams. In the present investigation, it is concluded that the river water is not suitable for irrigation and drinking purposes.

Acknowledgment:

Authors are very much thankful to Prof. Atish Gawas, Mr. Prasad Kankekar of this University for their kind cooperation and constant encouragement.

5. References:

[1] APHA, "Standard methods for the examination of water and wastewater." (American Public Health Association), Washington DC, 1998, 20th edn.

[2] Aravindan, S., "Integrated hydro-geological studies in hard rock aquifer system of Gadilam River basin", Tamil Nadu, India. Ph D thesis, Bharathidasan University, thiruchirappalli, , p. 110, 1999.

[3] Balasubramanian, A., "Hydrogeological investigations in the Tambraparani river Basin." Tamil Nadu, Ph D thesis, University of My-sore, p. 345 ,1986.

[4] Back, W. and Hanshaw, B. B. "Advances in hydro-science." In Chemical Geohydrology, Academic Press, New York, vol. II, p. 49, 1965.

[5] Back, W.," Techniques for mapping of hydrochemical facies". USGS Prof. Pap., vol. 424D, pp 380-3821961.

[6] Ballukraya, P. N. and Ravi, R., "Characterization of groundwater in the unconfined aquifers of Chennai city, India." J. Geol. Soc. India, 1999, 54, 13-22.

[7] Ballukraya, P. N. and Ravi, R., "Hydrogeology of Madras city aquifers." J. Geol. Soc. India, 45 page 87-96, 19995,.

[8] Bonofer, A., "Manali industrial town and water pollution- Report of Observer Research Foundation," Chennai, India, 2004.

[9] Eaton, E. M., " Significance of carbonate in irrigation water." Soil Sci., vol 69, page 123-133. 1950,

[10] Gnasundar, D. and Elango, L., "Groundwater quality assessment of a coastal aquifer using geoelectrical techniques". J. Environ. Hydrol., vol 7, pg 1-8. 1999

[11] Handa, B. K., "Modified classification procedure for rating irrigation waters." Soil Sci., vol 98, page 264-269.1964.

[12] Handa, B. K.," Modified Hill-Piper diagram for presentation of water analysis data." Curr. Sci., vol 34, page 313-3141965.

[13] Hem, J. D., "Study and interpretation of the chemical characteristics of natural water." USGS

ISSN 2229-5518

Water Supply Paper, 2254, PP.117-120, 1985.

[14] Kelley, W.P. "Permissible composition and concentration of irrigation waters." Proc. ASCE, 1940, 66,607.

[15] Kumaresan and P. Riyazuddin, 2006. "Major ion chemistry of environmental samples around sub-urban of Chennai city." Current Science, 91 (12), 1668

[16] Kuppusamy, M. R. and Giridhar, V. V., "Factor analysis of water quality characteristics including trace metal speciation in the coastal environmental system of chenni Ennore." Environ. Int., 32, 174-437 ,2006,.

[17] Maucha, R., "The graphic symbolization of the chemical composition of natural waters." Hiderol, Kozlony, , 29, 1940.

[18] Ouyang, P., Nked-Kzza, Q. T. Wy, D., Shinde,. " Assessment of seasonal variation in surface water quality." Water Res., 40, 3800-3810, 2006 .

[19] Padma, S. and Periakali, P.," Physico-chemical and geological studies in Pulicat Lake, east coast India." Indian J. Mar. Sci., 28, 434-437, 1999.

[20] Piper, A. M,. " A graphic procedure in the geo-chemical interpretation of water analyses." USGS Groundwater Note no. 12, 1953.

[21] Stiff Jr. H. A., "The interpretation of chemical water analysis by means of patterns. "J. Petrol. Technol., ,vol 3, page 15-161951.

[22] Todd, D. K., "Groundwater Hydrology," Wiley, New York , p. 315, 1980.

[23] US Salinity Laboratory Staff, Diagnosis and improvement of soils and alkali soils. US Department of Agricultural Hand Book, 60, p. 160, 195,.

[24] Walton, W. C. "Groundwater Resources Evaluation," McGraw-Hill, New York,

[25] Wilcox, L. V., "Classification and use of irrigation water," US Department of agriculture, Washington DC, p. 19, 1955,

[26] Wilcox, L. V." The quality water for irrigation use." US Dept. Agric. Bull., 40 1962.

[27] Zaporozec, A., "Graphical interpretation of water quality data." Groundwater, Vol 10, page 32-43, 1972.