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Irrigational quality of Vamanapuram River, Kerala, India

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Abstract— Surface water is treated as an important source for irrigation around the world. The composition and concentration of dissolved components in water determine its quality for irrigation. One of the important considerations of water quality for irrigation is the saline or alkaline nature of the water. Characteristics of irrigational water can vary with the source of the water which may directly affects the management of soils and crops, and their associations. Assessment of irrigational quality of Vamanapuram river was carried out by means of Electrical Conductivity (EC) or Salinity index, Total Dissolved Solids (TDS), Chlorinity Index (CI), Sodium Adsorption Ratio (SAR), Soluble Sodium percentage (SSP) or Per cent Sodium (Na%), Residual Sodium Carbonates (RSC), Residual Sodium Bicarbonates (RSBC), Magnesium Adsorption Ratio (MAR), Permeability index (PI), Kelly's Ratio (KR), Corrosivity Ratio (CR) and Hardness. Water resources in the highland and midland parts of the study area (i.e., S1 to S16 and T1to T3) are within the range. Samples from lowland are highly influenced by salinity, Fe and chlorinity.

Index Terms— Vamanapuram, irrigational quality, EC, TDS, CI, SAR, SSP, Na%, RSC, RSBC, MAR, PI, KR, CR

1 Introduction

Rivers are historically recorded as the centre of civilization and development. The streams and their associated floodplains have immense contribution in their origin and cultural progress and still remain so. The Nile River Valley Civilization started at the northern most peak of the Nile River at the time of the Neolithic Revolution. Around 4000 B.C the Yellow (Hueng He) River valley Civilization began in China. In India, The Indus River Valley Civilization started about 2500 B.C. along the south-western part of the Indus River. The largest city was Mohenjo-Daro and settlements stretched all along the river have the patent of all our cultural resources.

Urbanization and adopted trends in land use pattern or input of urban stress to natural streams, challenges the integrity of water quality. Water used for agriculture should be in range of standard chemical behaviour. The land practices and nutrients and pesticides to rivers as leachout shall affect biological integrity. The differences in the characteristics of water are a result of variations in the geology, climate and climatic parameters[1].

Deshpande and Aher[2] attempted to understand water rock interaction process and to investigate the concentration of the total dissolved constituents present in the ground water with respects to the standards of safe potable water. An attempt has been made to evaluate the quality of groundwater for irrigation purpose[3,4].

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2 Methodology

Sampling and analysis of quality parameters such as pH, electrical conductivity (EC), total dissolved solids (TDS) or salinity index, total hardness (TH) and Chlorinity Index (CI) or chlorinity were estimated by standard methods[5] and the important irrigational quality parameters were computed by the following equations:

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

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

$$RSC = (CO_3 + HCO_3) - (Ca + Mg) \quad (3)$$

$$RSBC = HCO_3^{-} - Ca^{2+} \quad (4)$$

$$MAR = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} \times 100 \quad (5)$$

$$PI = \frac{Na^{+} + \sqrt{HCO_3^{-}}}{Ca^{2+} + Mg^{2+} + Na^{+}} \times 100 \quad (6)$$

$$KR = \frac{Na^{+}}{Ca^{2+} + Mg^{2+}} \quad (7)$$

$$CR = \frac{\frac{Cl^{-}(mg/L)}{35.5} + \frac{SO_4^{2-}(mg/L)}{48}}{\frac{[HCO_3^{-}(mg/L) + CO_3^{2-}(mg/L)]}{50}} \quad (8)$$

All the ionic concentrations in the above equation are expressed in meq L^{-1} and %Na, MAR and PI in %. 25 samples (19=river, 4=tributary, 1=estuary) were collected for each season (monsoon- MON, Post-monsoon-POM and Pre-monsoon-PRM) approximately 5 km interval (mainstream).

The sixth order Vamanapuram river originates from the upper slope of Western Ghats in southern Kerala and debouches into the Anchuthengu lake. It flourishes 29 panchayats and Attingal municipality. Majority of study area falls in highlands, 56.1% (385 sq.km) followed by midlands (40.7%) and lowlands 3.2% (22 sq.km). About 1/56th of the area of Kerala State is managed altogether by this small catchment river and its tributaries which meets 1, 18, 499 people[6]. Midland to lowland regime of main stream (43 km) possesses 16 pump houses and 11 water intake points. Fig.1 shows the study area with drainage networks and sampling points. The study area faces 41% degradation since 1967 to 2011 in paddy. The assessment of irrigational quality of surface waters of Vamanapuram river is the main objective of the study.

3 Results and Discussion

The concentration of chemical constituents in irrigation water directly affects plant growth through toxicity or deficiency, or indirectly by altering nutrient unavailability[7,8]. Use of polluted water for irrigation can create four types of problems, namely toxicity, water infiltration, salinity and miscellaneous[7]. Irrigational water quality of surface water samples of VRB is depicted in Table 1.

3.1. Electrical conductivity (Salinity index)

The most influential potent tool in water quality guideline on crop productivity is the water salinity hazard as measured by electrical conductivity (EC). Salinity is related to TDS and EC; it reflects the TDS in water. High concentrations of TDS and EC in irrigation water may increase the soil salinity, which affects the plant salt intake.

EC of the VRB in three seasons and comparison with the EC classification table[9] and it was found that majority of the water samples (20) in the VRB are low saline water and are excellent for irrigational purpose according to the values of EC in all the three season. A few exemptions are observed in the water samples which were collected from the tributaries of Vamanapuram river and are showing excessive salinity (T4) in all the seasons, are unsuitable for irrigational purpose (Table:2).

3.2. Total Dissolved Solids (TDS)

High cationic representation in the irrigation water may prove to be injurious to plants and animals[10]. When present in excessive quantities, they reduce the osmotic activities of the plants and may prevent adequate aeration, causing injuries of plant growth.

Table: 3 showing the classification of the water samples based on the TDS content[11]. From the table it could be understood that majority of the water samples (20) were best quality in all seasons and can be used for irrigation without any treatment.

3.3. Chlorinity Index (CI)

The chloride ion can be toxic to plants having high salt tolerance when taken up by their roots and absorbed through their leaves. When water samples in the study area were classified based on the chlorinity index[12,13] majority of the surface water samples (20) were fall in Class I and are suitable for irrigational purpose due to the low saline nature but some of the samples from the study area were included in class V are Unsuitable for irrigation (Table: 4).

3.4. Sodium Adsorption Ratio (SAR)

Sodium adsorption ratio is the proportion of sodium to calcium and magnesium, which affect the availability of the water to the crop[14]. The sodium adsorption ratio gives a clear idea about the adsorption of sodium by soil; higher values of sodium in irrigation water resulting in poor drainage. High values of SAR imply a hazard of sodium replacing adsorbed calcium and magnesium, a situation ultimately damaging to soil structure[15].

The SAR is used to predict the sodium hazard of high carbonate waters especially if they contain no residual alkali[11].

The alkalinity hazard of water samples are shown in the Table: 5. According to Rao[16], majority of the water samples were fall within the excellent quality during the MON (24), POM (20) and PRM (19) seasons. In the POM and PRM seasons some of the samples were (S5 and S6) become unsuitable due to sodium hazard. Comparatively in MON the water showed high quality, it might be due to the high dilution.

USSL Diagram

Based on the sodicity (USSL) diagram the surface water samples are classified and shown in Fig. 2 to 4. The USSL diagram of the water samples of VRB indicates that majority of the samples have low SAR value. In all the three seasons, out of 25 samples, 19 samples lies in C1-S1 field and it is considered as good water category for irrigation use.

In PRM, six water samples were fall in the C4-S4 category, while in MON it was only one and in POM it is five. It indicates very high alkali hazard and these waters are unsatisfactory for irrigation under normal condition. Three water samples in MON were fall in the C4-S3 category and it denotes very high in salinity and high sodicity waters and two samples were in the C4-S2 category (very high in salinity and medium sodicity). In POM, one sample was in the C3-S1 field indicates high salinity and low sodicity. The exceptional character (very high alkali hazard) shown by the six surface water samples of VRB are in close vicinity of salt waters from sea and estuary; and the fluctuations in the season might be due to the dilution.

3.5. Soluble Sodium Percent (SSP) or Percent Sodium (% Na)

The pore space of the soil contains air and water and is required for the proper growth of plants. The Sodium content of water reacts with the soil and accumulates in the pore spaces thus reducing its permeability. Water with a SSP greater than 60% will results in breakdown in the soil's physical properties may due to sodium accumulations[17].

Table: 5 shows the alkalinity hazard of water samples in the three seasons. The range of % Na in the samples of the area in MON is ranging 11.04 - 70.11%. Among the 25 samples collected only 14 samples are within the permissible limit of SSP and are safe for irrigational purpose. The remaining 11 samples show a value greater than 50% means they are not suitable for direct irrigation. In POM, SSP of Vamanapuram River (VR) ranges from 2.81 to 90.25%; while in PRM it is 12.92 - 93.66%. In both the seasons 19 samples are found safe while the rest 6 samples were not suitable for direct irrigation due to high SSP (>80%) in the waters of that area. Monsoon degradation appeared might be of high diagenesis and agricultural run-off.

Wilcox's Diagram

Wilcox[18] suggested a graphical method for knowing the suitability of water for irrigation purposes. In this diagram % Na is plotted against EC. The proposed method is widely used and is based on percent sodium and electrical conductivity plot, because Na+ concentration reacts with soil to reduce its permeability[19]. The diagram consists of five distinct areas i.e., excellent to good, good to permissible, permissible to doubtful, doubtful to unsuitable and unsuitable. The data was calculated and subsequently plotted on the Wilcox diagram (Fig. 5 - 7). On the basis of this diagram, throughout the year most of the water samples of VRB (19) fall under the category I (excellent to good) and it denotes the suitability of that water for irrigation purposes. The remaining 6 water samples were fall in the category IV (unsuitable).

3.6. Residual Sodium Carbonate (RSC)

Residual sodium carbonate (RSC) has been calculated to determine the hazardous effect of carbonate and bicarbonate on water for agricultural purpose. RSC gives an account of calcium and magnesium in the water sample as compared to carbonate and bicarbonate ions[20]. High concentration of CO_3 and HCO_3 in water represents alkalinity and is unfavourable for agriculture uses[20,21].

If RSC>2.5 meq L^{-1}, the water is unsuitable for irrigation[22]. Table: 6 clearly shows that in all the three seasons of the water samples in the VRB were <1.25 meq L^{-1} and fall within the safe category for irrigation throughout the year. Most of the water samples of VRB (19) fall under the category, I (excellent to good) and it denotes the suitability of that water for irrigation purposes.

The remaining 6 water samples were fall in the category IV (unsuitable).

3.7. Residual Sodium Bicarbonate (RSBC)

The concentration of bicarbonate and carbonate also influences the suitability of water for irrigation purpose. The water with high RSBC has high pH. Therefore, land irrigated with such water becomes infertile owing to deposition of sodium carbonate[10].

Mandel and Shiftan[23] reported bicarbonate content more than 1 meq L^{-1} (epm) or 60 mg L^{-1} (mg G^{-1}) in the water is necessarily attributed from the biological activities of plant roots, from the oxidation of organic matter included in the soils and in the rock, and from various chemical reactions. Table: 6 alleges RSBC in VR for all the three seasons which is <5 meq L^{-1} and under safe category for irrigation.

3.8. Magnesium Adsorption Ratio (MAR)

Magnesium content of water is considered as one of the most important qualitative criteria in determining the quality of water for irrigation. More magnesium in irrigation water will adversely affect soil potential as become more alkaline and reduce crop yield[24].

If MAR of more than 50% in a waterbody it would make the water poisonous to plants. The MAR of the water samples of VRB in MON, POM and PRM seasons are tabulated in Table: 7. MAR in the water samples of the VR in MON season ranges from 7.43 to 96.22 percent. Only 7 samples fall in the harmless and suitable category and the remaining 18 samples were in harmful and unsuitable for irrigation due to magnesium hazard. In POM and PRM also more than 50% of the samples from VRB show high magnesium content and fall in the dangerous category thus are unfit for irrigational purpose. From the above table, the Magnesium ratios were found to be more than the permissible limit in all water sample locations, except in few locations. Source of high Mg ratio in the irriagational water (VR) might be lithological[25].

3.9. Permeability Index (PI)

Ayers and Westcot[7] reported that, HCO_3^- is merely not toxic, but when it exceeds 2 meq L^{-1} in irrigation water it will cause deficiency of zinc in paddy rice. The soil permeability is affected by consistent use of unsuitable water which increases the presence of sodium, calcium, magnesium and bicarbonate in the soil[26]. The Permeability index of VR in three seasons are tabulated in Table: 8

According to Doneen[27], in MON season, the PI of the surface water samples are ranging from 67.36 to 280.10 (%) and majority of the water samples (19) of the study area were fall in the class III, and thus the water samples are unsuitable for direct irrigation. In POM the PI values ranges from 15.17 to 90.62(%) and 19 samples were fall in good category and those are suitable for direct irrigation while the rest 6 samples were unfit for irrigation because they fall in the class III. The PI values recorded in MON are ranging from 30.67 to 101.07(%). Here out of the 25 samples collected 16 samples were fit for irrigation while the remaining 9 samples were unfit for irrigation due to the high vales of PI in that season. When we look in an overall in monsoon the water samples of VR become unsuitable than in POM and PRM; may be due to the runoff and leaching during raining the water samples of that area get over loaded with sodium, calcium, magnesium, etc.

3.10. Kelly's Ratio (KR).

Surface water having Kelly's ration more than one is considered unsuitable for irrigation. Kelly's ratio of the surface water samples of VR ranges between 0.14 to 2.29 meq L^{-1}, 0.02 to 9.08 meq L^{-1} and 0.09 to 12.99 meq L^{-1} in MON, POM and PRM, respectively. As per this criterion majority of the surface water samples of VR for all the three seasons are greater than 1 and are not suitable for irrigation purposes (Table: 9).

3.11. Corrosivity Ratio (CR)

The groundwater with corrosivity ratio < 1 is considered to be safe for transport of water in any type of pipes, whereas >1 indicate corrosive nature and hence not to be fit for transported through metal pipes, only noncorrosive pipes have to be used for transporting water[28].

The intensity of corrosion depends upon certain physical factors like temperature, pressure and velocity of flow of water[7]. Higher concentration of Cl^- and SO_4^{2-} also increase the corrosion rate[29]. On the other hand, bicarbonate, even in the absence of calcium, inhibits the corrosion of steel. Therefore, the bicarbonate, chloride and sulfate present in domestic waters appear to be fundamental factors determining the corrosiveness of waters at pH 7 to 8. Corrosivity ratios are applicable only in the neutral pH range (7 to 8) and in the presence of dissolved oxygen.

In the neutral pH range (7 to 8) and the presence of dissolved oxygen, ratios below about 0.2 meq L^{-1} indicate general freedom from corrosion, whereas increasingly higher ratios are indicative of progressively more corrosion waters.

Table: 10 clearly explicit that, the corrosivity ratios of VR for all the three seasons (<0.2) and the water is free from corrosion and can be safely transported through pipelines.

3.12. Hardness

According to Sawyer and McCarty's[30] total hardness classification scheme (Table: 11), the water samples of VR in monsoon season shows better quality than in POM and PRM. Out of the 25 samples collected 19 samples were soft and the rest 2 samples were hard and the 4 samples were very hard due to the presence of carbonates and bicarbonates. In POM only 8 samples were within the class I (very soft) and the rest 9,2 and 4 samples were included in the class II, III and IV, respectively indicate that those samples were become moderately hard, hard and very hard during the POM and become unsuitable.

4 Conclusion

Water quality analysis of water samples covering the main stream, major tributaries and river estuary for MON, POM and PRM has revealed that physico-chemical parameters do show both spatial and temporal variations. In order to assess the suitability for irrigation, the chemical data has been subjected to various indices like chlorinity index, SAR, USSL diagram, SSP, %Na, Wilcox diagram, Residual sodium carbonate (RSC), MAR, RSBC, PI, Kelly's Ratio (KR), CR, etc. It has been found that majority of water in VR is good for irrigation especially water from S1 to S16 (inclusive of tributaries, T1 to T3) locations of river, *i.e.*, highland to lower-midland. However, the lower reaches (S17-S20 &T4) have higher salinity and not suitable for irrigation, only because of the saline water intrusion, an implication of bedlowering-anthropogenic upshot.

5 References

[1] M.M. Rahman, and A.Q.M. Mahbub, "Groundwater depletion with expansion of irrigation in Barind Tract: a case study of Tanore Upazila". Journal of Water Resource and Protection, 4(08), 567, 2012.

[2] S.M. Deshpande, and K.R. Aher, "Hydrogeoelectrical Studies in Harsul area of Aurangabad, Maharashtra, India". Special issue on Geochemistry and Geophysics of Earth Materials and Environment, Jour. of Applied Geochemistry, pp 10-15, 2012.

[3] A.J. Ahamed, S. Ananthakrishnan, K. Loganathan, and K. Manikandan, "Assessment of groundwater quality for irrigation use in Alathur Block, Perambalur District, Tamilnadu, South India". Applied Water Science, 3(4), 763-771, 2013.

[4] S.M. Shah, and N.J. Mistry, "Seasonal variation of groundwater quality in a part of Vadodara District for irrigation, Gujarat, India". IOSR Journal of Environmental Science, Toxicology and food Technology, 7(2): 46-50, 2013.

[5] APHA, "Standard methods for the examination of water and wastewater", A.D. Eaton, L.S. Clesceri, E.W. Rice, A.E. Greenberg, and M.A.H. Franson, (Eds.) 21st Edition. American Public Health Association (APHA), the American Water Works Association (AWWA), and the Water Environment Federation (WEF), 2005.

[6] Census of India, "Provisional Population Totals: various States", Paper I & II, 2011.

[7] R.S. Ayers, and D.W. Westcot, "Water Quality for Agriculture", FAO Irrigation and Drainage Paper 29 rev 1. FAO, UN, Rome 174p, 1985.

[8] D.R. Rowe, and I.M. Abdel-Magid. "Handbook of Wastewater Reclamation and Reuse". CRC Press, Inc. p. 550, 1995.

[9] I.I.M. Raghunath, "Groundwater", II (Edn.) Wiley Eastern Ltd, New Delhi, India, 1987.

[10] G.I. Obiefuna, and A. Sheriff, "Assessment of shallow ground water quality of Pindiga Gombe Area, Yola Area, NE, Nigeria for irrigation and domestic purposes". Res. J. Environ. Earth Sci., 3: 131-141, 2011.

[11] C.J. Robinove, R.H. longfort, and J.W. Brook, "Saline water resource of North Dakota", US Geol. Surv. Water Supply Paper 1428, pp: 72, 1958.

[12] B. Mills, "Interpreting water analysis for crop and pasture". File No. FS0334, DPI's Agency for Food and Fibre Sciences, Toowoomba, 2003.

[13] K.P. Singh, D. Malik, V.K. Singh, and S. Sinha, "Evaluation of groundwater quality in Northern Indo-Gangetic alluvium region", Env. Monit. Assess., 112 211-230, 2006.

[14] U.S. Salinity Laboratory Staff, "Diagnosis and improvement of saline and alkali soils". U.S. Dept. Agriculture Hand book, No. 60, 160p, 1954.

ISSN 2229-5518

[15] J.D. Hem, "Study and interpretation of the chemical characteristics of natural water', Scientific publishers, Jodhour, India, 1991.

[16] N.S. Rao, "Nitrate pollution and its distribution in the ground water of Srikakulam district, Andhra Pradesh, India", Environ. Geology, 51, pp 631-645, 2006.

[17] L. Khodapanah, W.N.A. Sulaiman and N. Khodapanah, "Groundwater Quality Assessment for Different Purposes in Eshtehard District, Tehran, Iran". European Journal of Scientific Research, 36(4), pp 543-553, 2009.

[18] L.V. Wilcox, "Classification and use of irrigation waters", U.S. Depatment of Agriculture. Circ. 969, Washington, D.C., 1955.

[19] D.K. Todd, "Groundwater Hydrology", John Willy and Sons, Ins, IJSER International Journal of Scientific & Engineering Research, Volume 6, Issue 10, October-2015 807 ISSN 2229-5518 IJSER © 2015 http://www.ijser.org New York, 132-137, 1980.

[20] F.M. Eaton, "Significance of carbonates in irrigation water"., Soil Sci., 69 123-133, 1950.

[21] L.A. Richard, "Diagnosis and improvement of saline and alkali soils",

Agric Handbook 60, USDA, Washington D.C., 160p, 1954.

[22] N. Aghazadeh, and A.A. Mogaddam, "Assessment of groundwater quality and its suitability for drinking and agricultural uses in the Oshnavieh area, Northwest of Iran". Journal of environmental protection, 1(01), 30, 2010.

[23] S. Mandel, and Z.L. Shiftan, "Ground Water Resources Investigation and Development", Academic Press Inc., New York, 1981.

[24] D.M. Joshi, A. Kumar and N. Agrawal, "Assessment of the irrigation water quality of River Ganga in Haridwar District India". J. Chem., 2(2): 285-292, 2009.

[25] K. Pandian, and K. Sankar, "Hydrogeochemistry and Groundwater Quality in the Vaippar River Basin, Tamil Nadu", Journal of Geological Society of India, 69, pp 970-982, 2007.

[26] S.N. Chandu, N.V. Subbarao, and S.R. Prakash, "Suitability of Groundwater for domestic and irrigational purposes in some parts of Jhansi District, U.P.", Bhu-Jal News, vol. 10(1), pp. 12-17, 1995.

[27] L.D. Doneen, "Notes on water quality in agriculture", water science and engineering, 1964.

[28] J.W. Ryner, "A new index for determining amount of calcium carbonate scale formed by water", Jour. Amer. Water Assoc. v. 36. pp. 472-486, 1944.

[29] V. Raman, "Impact of corrosion in the conveyance and distribution of water". Jour. I.W.W.A; v. xv(11) pp. 115-121,1985.

[30] C.N. Sawyer, and P.L. McCarty, "Chemistry for Sanitary Engineers", 2nd ed. McGraw – Hill: New York, 1967.

Table: 1 Season-wise combined chemical composition and irrigational quality parameters of surface water samples

MONSOON													
	pH	EC	TDS	CI	SAR	SSP	RSC	RSBC	MAR	PI	KR	CR	TH
S 1	7.41	50.52	14	42.55	0.18	16.04	-0.22	0.49	87.11	95.59	0.14	0.00	40
T1	7.48	60.30	2	35.46	0.32	30.86	-0.01	0.19	49.13	139.36	0.35	0.00	20
S 2	7.12	53.22	14	36.17	0.27	27.93	0.19	0.39	49.13	167.53	0.29	0.00	20
S 3	7.27	51.83	22	28.37	0.23	21.17	0.19	0.69	82.84	138.13	0.21	0.00	30
T 2	7.43	83.06	29	35.46	0.35	32.82	0.39	0.69	74.34	185.61	0.38	0.00	20
S 4	7.64	57.62	17	42.55	0.31	30.54	0.19	0.49	74.34	166.49	0.34	0.00	20
S 5	7.66	57.22	12	35.46	0.45	46.47	0.39	0.49	49.13	262.21	0.69	0.00	10
S 6	7.83	63.61	2	35.46	0.32	30.75	-0.01	0.29	74.34	140.27	0.35	0.00	20
S 7	7.74	69.04	20	28.37	0.34	41.59	0.39	0.49	49.13	280.10	0.53	0.00	10
S 8	7.54	72.34	33	24.82	0.47	48.65	-0.01	0.09	49.13	167.04	0.74	0.00	10
S 9	8.23	74.91	15	28.37	0.37	35.63	-0.01	0.29	74.34	138.75	0.40	0.00	20
S 10	7.34	79.12	83	42.55	0.24	19.56	-0.42	0.29	87.11	81.06	0.19	0.00	40
S 11	7.61	76.42	15	46.09	0.29	24.91	-0.02	0.39	65.89	120.36	0.26	0.00	30
S 12	7.5	88.52	25	49.64	0.37	34.22	0.19	0.49	74.34	163.00	0.41	0.00	20
T 3	7.27	163.50	61	49.64	0.80	50.35	-0.21	-0.01	49.13	104.36	0.88	0.00	20
S 13	7.59	93.88	41	56.73	0.44	37.53	0.19	0.49	74.34	159.85	0.49	0.00	20
S 14	7.67	98.45	3	35.46	0.49	39.54	0.19	0.49	74.34	157.79	0.54	0.00	20
S 15	7.63	96.47	39	46.09	0.43	36.87	0.59	0.89	74.34	197.52	0.48	0.00	20
S 16	7.38	102.50	24	53.19	0.51	40.08	-0.01	0.29	74.34	134.80	0.56	0.00	20
S 17	7.43	3967	1295	531.86	6.53	69.58	-3.69	-0.24	80.41	74.61	2.23	0.01	210
S 18	7.49	6336	2162	914.79	8.09	67.05	-7.94	0.08	96.22	69.01	1.98	0.02	410
T 4	7.17	2119	827	351.02	4.77	64.25	-3.08	-0.24	77.17	71.37	1.76	0.01	180
S 19	7.41	9901	3499	1545.93	8.90	65.62	-10.87	-2.34	74.34	67.36	1.86	0.03	560
S 20	8.1	12050	4318	1886.31	11.73	70.11	-12.67	-1.91	82.31	71.12	2.29	0.05	640
L	7.57	74770	29589	13289.28	32.56	69.36	-106.89	-98.87	7.43	69.20	2.22	0.15	24500
POST-MONSOON													
	pH	EC	TDS	CI	SAR	SSP	RSC	RSBC	MAR	PI	KR	CR	TH
S 1	7.02	28.70	77	56.73	0.08	5.57	-1.65	-0.23	69.26	33.50	0.04	0.00	100
T1	7	39.50	112	63.82	0.06	2.81	-3.87	0.08	92.62	16.41	0.02	0.00	210

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S 2	7	31.30	69	56.73	0.06	2.83	-3.77	-0.02	92.25	15.17	0.02	0.00	200
S 3	7.1	31.60	105	56.73	0.26	16.89	-0.93	-0.12	65.89	52.34	0.17	0.00	60
T 2	7.43	44.20	73	56.73	0.10	6.38	-2.15	-0.32	81.29	17.88	0.05	0.01	110
S 4	6.92	36.30	87	56.73	0.12	10.52	-0.63	-0.02	59.16	64.29	0.08	0.00	50
S 5	7.25	40.40	65	56.73	0.11	9.36	-1.04	-0.43	49.13	40.26	0.07	0.00	60
S 6	7.08	40.60	49	70.91	0.14	13.70	-0.43	-0.23	24.35	78.23	0.11	0.00	40
S 7	6.85	43.80	58	56.73	0.09	6.38	-1.84	-0.22	79.43	25.36	0.05	0.00	100
S 3	7.1	31.60	105	56.73	0.26	16.89	-0.93	-0.12	65.89	52.34	0.17	0.00	60
S 8	7.14	45.30	79	56.73	0.09	6.27	-1.05	0.17	65.89	50.58	0.04	0.00	90
S 9	7.23	47.30	83	63.82	0.13	10.66	-0.24	0.37	49.13	82.15	0.08	0.00	60
S 10	7.01	55.30	126	56.73	0.11	10.65	-0.24	0.17	39.16	87.28	0.08	0.00	50
S 11	7.11	51.00	94	49.64	0.12	8.37	-0.87	-0.46	24.35	56.47	0.07	0.00	80
S 12	7.07	49.90	112	70.91	0.07	4.28	-2.56	-0.33	77.98	21.51	0.03	0.00	140
T 3	7.17	80.40	123	85.10	0.24	19.61	-0.43	-0.23	24.35	79.58	0.18	0.00	30
S 13	7	52.30	96	78.01	0.09	5.85	-1.94	0.09	90.62	27.54	0.04	0.00	110
S 14	7.54	53.10	97	70.91	0.10	8.33	-1.04	-0.02	70.71	47.25	0.06	0.00	70
S 15	7.39	55.70	125	63.82	0.11	7.64	-1.44	-0.02	77.17	38.00	0.06	0.00	90
S 16	7.2	60.50	118	70.91	0.12	8.69	-1.35	-0.33	61.68	37.56	0.07	0.00	80
S 17	7.25	9610	6389	3262.04	30.17	86.53	-11.06	-8.01	26.58	87.06	6.30	0.08	1900
S 18	7.14	12700	8470	5389.46	40.52	90.25	-9.66	-6.01	36.68	90.62	9.08	0.17	2100
T 4	7.61	1320	803	992.80	5.06	63.36	-4.17	-2.85	29.50	67.40	1.69	0.03	800
S 19	7.39	11300	7564	4538.50	28.73	83.90	-15.29	-10.01	33.43	84.37	5.11	0.09	3100
S 20	7.65	11300	7515	5814.95	28.64	84.04	-14.89	-10.01	31.67	84.52	5.16	0.11	2900
L	7.77	39300	30835	18721.30	36.19	69.86	-125.00	-114.84	8.07	69.75	2.28	0.22	30500
PRE-MONSOON													
S 1	7.08	45.10	151	134.74	0.17	14.13	-1.03	0.19	85.28	49.50	0.10	0.00	70
T1	7.16	34.70	103	127.65	0.19	12.97	-1.95	-0.12	81.29	30.67	0.09	0.00	110
S 2	7.24	64.10	68	120.55	0.20	16.75	-0.73	0.08	65.89	62.29	0.13	0.00	60
S 3	7.11	54.80	92	120.55	0.18	15.39	-0.73	0.29	82.84	62.13	0.12	0.00	60
T 2	6.97	64.40	118	120.55	0.28	23.65	-1.03	0.19	85.28	52.14	0.16	0.00	70
S 4	7.09	41.50	91	113.46	0.23	22.63	-0.63	-0.02	59.16	66.76	0.16	0.00	50
S 5	7.07	52.20	110	127.65	0.25	22.96	-0.83	-0.02	65.89	57.98	0.16	0.00	60
S 6	7.23	61.20	95	127.65	0.37	37.14	-0.22	-0.02	32.56	101.07	0.33	0.00	30
S 7	7.21	67.90	112	113.46	0.22	16.07	-1.64	0.19	89.68	37.93	0.11	0.00	100
S 8	7.22	61.30	104	127.65	0.25	19.44	-1.25	-0.23	61.68	45.99	0.14	0.00	80
S 9	6.95	65.10	102	127.65	0.29	23.06	-1.03	0.19	85.28	52.39	0.17	0.00	70
S 10	7.17	68.20	101	120.55	0.35	29.45	-0.63	-0.02	59.16	68.91	0.24	0.00	50
S 11	6.93	70.90	112	127.65	0.27	13.90	-1.07	-0.66	24.35	53.27	0.15	0.00	80
S 12	7.28	73.70	114	134.74	0.25	17.31	-1.64	0.19	89.68	38.63	0.12	0.00	100
T 3	7.25	73.20	118	141.83	0.29	19.88	-1.33	0.29	88.54	46.64	0.15	0.00	90
S 13	7.03	73.80	119	170.19	0.25	16.22	-1.65	0.18	81.29	41.27	0.12	0.00	110
S 14	7.06	142.00	114	78.01	0.20	12.92	-2.15	0.29	92.06	32.48	0.09	0.00	130
S 15	7.36	73.50	111	163.10	0.29	23.38	-0.63	0.39	82.84	69.03	0.19	0.00	60
S 16	7.15	78.80	115	177.29	0.23	15.46	-1.44	0.18	79.43	44.17	0.11	0.00	100
S 17	7.74	43200	35587	2907.47	30.83	87.61	-12.07	-7.81	33.64	86.82	6.12	0.06	2500
S 18	7.77	41500	32748	2588.36	42.02	90.95	-10.48	-5.81	42.54	90.61	8.97	0.06	2600
T 4	7.77	43400	34560	2623.82	54.10	93.66	-7.97	-3.51	51.51	93.54	12.99	0.04	2400
S 19	7.8	42200	33864	2517.45	47.63	91.66	-11.09	-5.61	46.50	91.41	9.81	0.04	3000
S 20	7.8	41000	32376	2538.72	46.28	91.58	-10.38	-5.51	43.58	91.47	9.79	0.04	2700
L	7.88	40200	30728	2311.80	48.71	93.20	-6.86	-3.21	46.50	93.43	12.29	0.03	2000

pH= no unit, EC = μS cm^{-1}, SAR, RSC, RSBC, CR & KR = meq L^{-1}; MAR, PI, SSP= %; TDS, CI & TH (mg L^{-1})

Table: 2 Salinity index

Sl. No.	Electrical Conductivity (µmhos/cm)		Type of water	Suitability for irrigation	No. of samples		
					MON	POM	PRM
1	Below 250		Low saline water (Excellent)	Entirely safe	19	19	19
2	250-750		Moderately Saline (Good)	Safe under practically all conditions	1	1	-
3	750-2250		Medium to high salinity water (Doubtful)	Safe only with permeable soil and moderate teaching	-	-	-
4	Above 2250		Unsuitable				
	i	2250-4000	High salinity	Unfair for irrigation	1	-	-
	ii	4000-6000	Very high salinity	Unfair for irrigation	-	-	-
	iii	Above 6000	Excessive salinity class	Unfair for irrigation	4	5	6

Table: 3 Range of Total Dissolved Solids for irrigation use

TDS (mg L-1)		Type of Water	No. of samples		
			MON	POM	PRM
1	<1,000	Non saline- Best quality water	20	20	19
2	1,000-3,000	Slightly saline- Water involving hazard	2	-	-
3	3,000-10,000	Moderately saline- Used for irrigation only with leaching and perfect drainage	2	4	-
4	>10, 000	Very saline- Unsuitable for irrigation	1	1	6

Table: 4 Cholrinity Index (CI)

Chlorinity (mg L^{-1})	Water Class	Type of Water	No. of samples		
			MON	POM	PRM
<375	I	Low	20	19	19
375-700	II	Moderate	1	-	-
700-925	III	High saline	1	1	-
925-1325	VI	Very high saline	-	-	-
>1325	V	Unsuitable for irrigation	3	5	6

Table: 5 Alkalinity hazard

Sodium (Alkali) Hazard Class	SAR	SSP (%Na)	Water class	Number of samples					
				SAR			SSP (%Na)		
				MON	POM	PRM	MON	POM	PRM
C1	<10	<20	Excellent	23	20	19	2	19	12
C2	10-18	20-40	Good	1	-	-	12	-	7
C3	18-26	40-80	Doubtful	-	-	-	11	2	-
C4	>26	>80	Unsuitable	1	5	6	-	4	6

Table: 6 The RSC and RSBC of surface water samples of VRB

Parameters	Range	Water Class	No. of samples		
			MON	POM	PRM
RSC	<1.25	Good (Safe)	25	25	25
	1.25-2.50	Doubtful (Moderate)	-	-	-
	>2.5	Unsuitable	-	-	
RSBC	<5	Safe	25	25	25
	5-10	Marginal	-	-	-
	>10	Unsuitable	-	-	-

Table: 7 MAR (Magnesium Hazard)

MAR (Magnesium Hazard)	Water class	Number of samples		
		MON	POM	PRM
<50	Harmless and suitable	7	12	7
>50	Harmful and unsuitable	18	13	18

Table: 9 Kelley's Ratio

Kelley's Ratio Range	Water class	No. of samples		
		MON	POM	PRM
>1	Unsuitable	19	19	19
<1	Suitable	6	6	6

Table: 8 Permeability index

PI	Class	Water class	Number of samples		
			MON	POM	PRM
<40	I	Excellent	-	10	4
40-80	II	Good	6	9	12
>80	III	Unsuitable	19	6	9

Table: 10 Corrosivity Ratio

Corrosivity Ratio range	Water class	Number of samples		
		MON	POM	PRM
<0.1	Safe	24	22	25
0.1-0.2	Slightly scale-Forming	1	2	-
0.2-0.3	Stable	-	1	-
0.3-0.4	Slightly corrosive	-	-	-
>0.4	Highly corrosive	-	-	-

Table: 11 Hardness (mg L-1)

Total hardness	Class	Water class	Number of samples		
			MON	POM	PRM
0-75	I	Soft	19	8	10
75-150	II	Moderately hard	-	9	9
150-300	III	Hard	2	2	-
>300	IV	Very hard	4	6	6

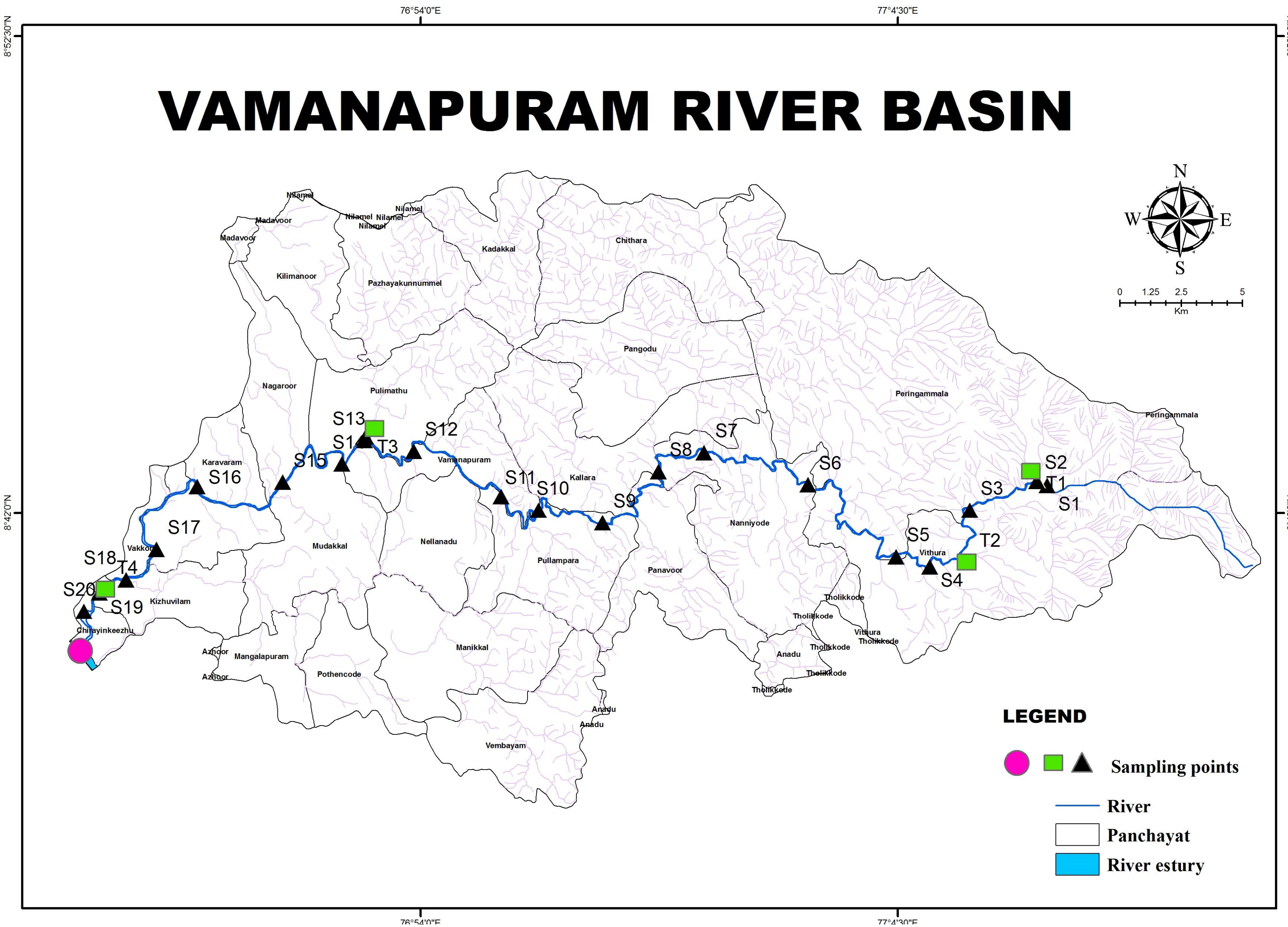

Fig.1 Study area showing water sampling points

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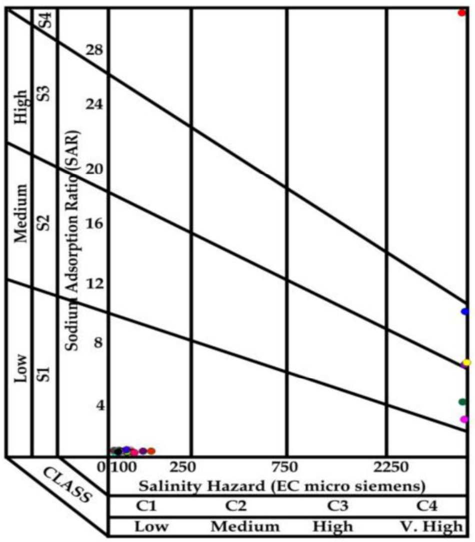

Fig. 2 USSL diagram – MON

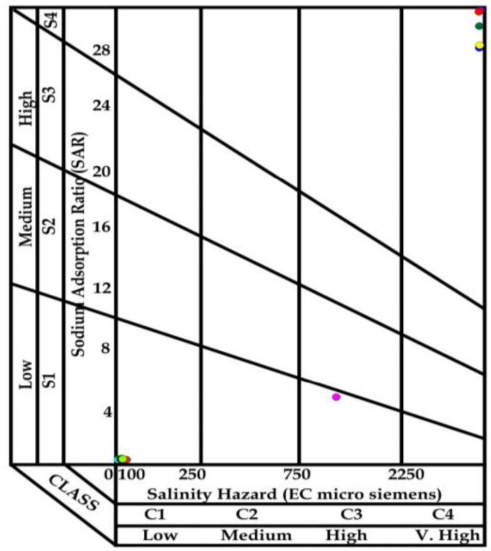

Fig. 3 USSL diagram – POM

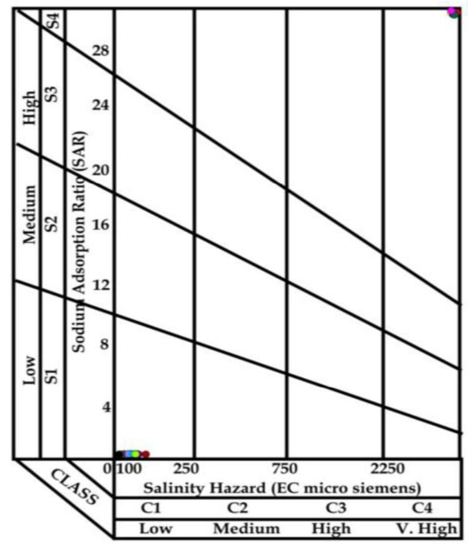

Fig. 4 USSL diagram – PRM

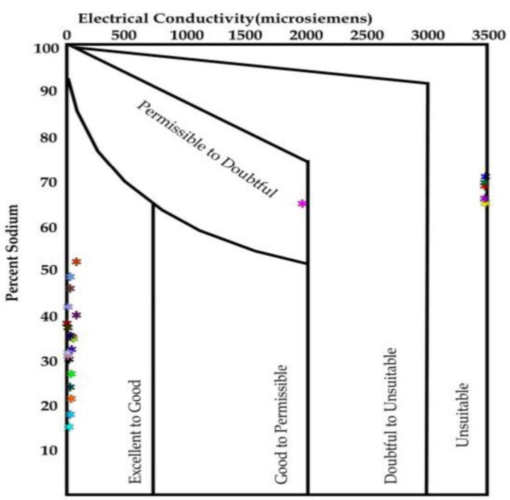

Fig. 5 Wilcox's diagram –MON

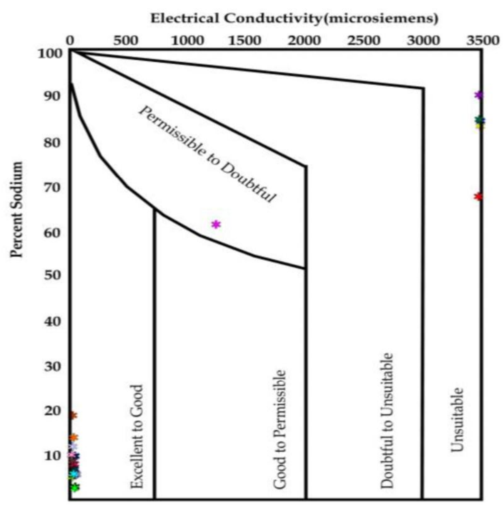

Fig. 6 Wilcox's diagram - POM

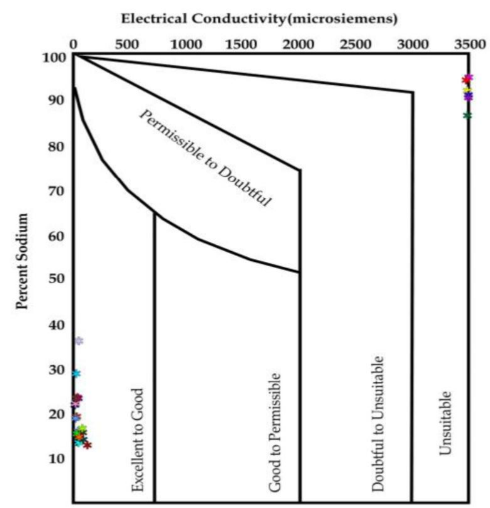

Fig. 7 Wilcox's diagram – PRM