WATER QUALITY INDEX (WQI), SPATIAL DISTRIBUTION OF SURFACE WATER IONS, AND SODIUM ADSORPTION RATIO (SAR) IN PAZHAYAR RIVER, KANNIYAKUMARI DISTRICT, TAMIL NADU, INDIA

[1]Ramkumar R and [2]Alhaji NMI.

[1]Research scholar, [2]Associate Professor, PG and Research Department of Chemistry, Khadir Mohideen College (Affiliated to Bharathidasan University), Adirampattinam, Tamil Nadu, India 614 701

ABSTRACT

The quality must be checked to prevent the deterioration of water availability for human consumption. Rapid industrialization and urbanization result in the deterioration of the water quality making the water unfit for human consumption and domestic purposes. Periodic assessment of the analytical parameters is essential for the protection, preservation and utilization of water resources. The present study gives a detailed analysis of physico-chemical parameters in Puthery, Ozhuginasery, Kothaigramam, Suchindram, Kakkamur south, Thamaraikulam north, Near the salt pan 2, Near the mangrove forest, Near the salt pan 1 and Sea mouth to assess the spatial distribution of surface water ions, water quality index (WQI) and sodium adsorption ratio (SAR) in Pazhayar river surface water from Kanniyakumari district, Tamil Nadu, India during 2016. The most of the station and all season in Pazhayar river surface water respect to sodium chloride type ions using geochemical evolution Piper trilinear diagram. Thus, the study concluded that the monsoon and post-monsoon seasons of Pazhayar river surface water are suitable for irrigation purposes in stations 1 to 6, but unsuitable for drinking purposes in all stations and seasons for human use.

Keywords: Pazhayar river, Water quality index, Sodium adsorption ratio, Spatial distribution.

INTRODUCTION

One of the most essential components of water is the existence of life on earth (Ramesh Kumar and Hemanth, 2018). Rivers are an important source of water that plays an important role in the development of living things (Gangwar *et al.*, 2013). Fresh water sources may be mainly in the form of rivers, lakes, rainwater, groundwater, etc. Besides the

need for water for drinking, water resources play a vital role in various sectors of the economy, such as agriculture, livestock production, forestry, industrial activities, hydropower generation, fisheries, and other human activities. The water quality index is one of the most effective tools for monitoring surface and ground water pollution and can be used effectively in water quality implementation (Gangwar *et al.*, 2013; Alam, 2010). However, they are having their river water polluted due to rapid industrialization, urbanization, and other developmental human activities (Gangwar *et al.*, 2013). The availability and quality of water, either surface or ground, have deteriorated due to some important factors like increasing population, industrialization, urbanization, etc. (Tyagi *et al.*, 2013).

Surface and ground water are the major sources of drinking water and are also used as an alternative source for the agricultural and industrial sectors around the world (Mishra and Bhatt, 2008; Dawood Sanad, 2014). The elements are present in water systems as dissolved ions and complexes, suspended colloids ions, and solids. The chemical composition of surface water's major cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) and anions (HCO_3, SO_4, Cl). Hydrochemistry provides a clear indication of the active recharge of shallow and deep aquifers by modern meteoric water. Carbonate dissolution was found to be the prevailing process controlling the surface water chemistry. Chemical quality was assessed for drinking purposes by comparing with WHO, Indian, and national standards and for irrigation purposes using empirical indices such as SAR (Akram *et al.*, 2011).

Tamil Nadu accounts for 4 % of the land area and 6 % of the population, but only 3 % of the water resources of the country (TNDR, 2005). Tamil Nadu is 46.52km3 /1,643TMC including 23.05km3 /814TMC groundwater potential of total water resource (Natarajan et al., 2017). The total surface water potential of the resources of Tamil Nadu state is 36 km 1 or 24864 M cum and there are 17 major river basins in the State with 61 reservoirs ((EPF, 2001; TNDR, 2005). Most of the surface water has already been tapped, primarily for irrigation which is the largest user. There are about 24 lakh hectares are irrigated by surface water through major, medium and minor schemes (TNDR, 2005). The quality must be checked to prevent the deterioration of water availability for human consumption. Rapid industrialization and urbanization result in the deterioration of the water quality making the water unfit for human consumption and domestic purposes. Periodic assessment of the analytical parameters is essential for the protection, preservation and utilization of water resources. In the aim of the present study to analysis of physico-chemical parameters in Puthery, Ozhuginasery, Kothaigramam, Suchindram, Kakkamur south, Thamaraikulam north, Near the salt pan 2,

Near the mangrove forest, Near the salt pan 1 and Sea mouth to assess the water quality index (WQI), spatial distribution of surface water ions and sodium adsorption ratio (SAR) in Pazhayar river surface water from Kanniyakumari district, Tamil Nadu, India during 2016.

MATERIALS AND METHODS

Location of sample collection and water chemical composition analysis

The Pazhayar river surface water sample was collected from Kanniyakumari district, Tamil Nadu, India, in the year of 2016. Samples were collected from Pazhayar river during the period of pre-monsoon, monsoon and post-monsoon. It was done at about 0.5m depth from the water surface, in pre-cleaned 2L plastic containers, after rinsing sufficiently in the same water. The samples were collected from ten different station points in each season. The water pH and temperature were analyzed immediately on the station points. All the sample bottles were stored in ice boxes till brought to the laboratory for analysis. The chemical composition analysis methods used for the analysis of various physic-chemical parameters were the same as given in Standard Methods for the Examination of water (APHA, 1967, 1980; APHA-AWWA-WPCF, 1976); Golterman *et al.*,(1978) and National Environmental Engineering Research Institute (NEERI, 1986).

Table 1: Location of water sample in Pazhayar river, Kanniyakumari district, Tamil Nadu, India.

S. No.	Station ID	Water sample collected place
1	**S1**	Puthery
2	**S2**	Ozhuginasery
3	**S3**	Kothaigramam
4	**S4**	Suchindram
5	**S5**	Kakkamur south
6	**S6**	Thamaraikulam north
7	**S7**	Near the salt pan 2
8	**S8**	Near the mangrove forest
9	**S9**	Near the salt pan 1
10	**S10**	Sea mouth

Water quality index calculation (WQI)

The water quality index (WQI) was calculated for evaluating influence of natural and anthropogenic activities based on several key parameters of surface water chemistry. To calculate the WQI, the weight has been assigned for the physico-chemical parameters according to the parameters relative importance in the overall quality of water for drinking water purposes. The assigned weight ranges from 1 to 5. The maximum weight of 5 has been assigned for nitrate and TDS, 4 for pH, EC, SO_4, 3 for HCO_3, Cl, 2 for Ca, Na, K and weight

1 assigned for Mg (Vasanthavigar *et al.*, 2010). The relative weight is computed from the following equation.

$$Wi = wi / \sum_{i=1}^{n} wi,$$

Wi is the relative weight

wi is the weight of each parameter

n is the number of parameters.

The quality rating scale for each parameter is calculated by dividing its concentration in each water sample by its respective standards (World Health Organization, 2011) and multiplied the results by 100.

$$qi = (Ci/Si) \times 100$$

qi is the quality rating

Ci is the concentration of each chemical parameter in each sample in milligrams per liter, **Si** is the World Health Organization standard for each chemical parameter in milligrams per liter according to the guidelines of the (WHO, 2011).

For computing the final stage of WQI, the SI is first determined for each parameter. The sum of SI values gives the water quality index for each sample

$$SIi = Wi \times qi$$

$$WQI = \sum_{SIi}$$

SIi is the sub-index of i^{th} parameter

qi is the rating based on concentration of i^{th} parameter

n is the number of parameters

Sodium Adsorption Ratio (SAR)

SAR VERIFICATION: Sodium absorption ratio (SAR) according to Richard, 1954 is an important parameter for determining the suitability of water for irrigation. It is a measure of alkali/sodium hazards to crops. Sodium absorbed clay minerals displace Mg^{2+} and Ca^{2+} ions.

Richard (1954) classified water standard for irrigation based on sodium absorption ratio i) 0-10 Excellent; ii) 10-18 Good; iii) 18-28 Fair and >28 Poor. On comparism it was shown that the inorganic elements of the surface water in the study area are excellent for irrigation purposes.

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+}+Mg^{2+}}{2}}}$$

where the concentration of ions Na^{+}, Ca^{2+} and Mg^{2+} is meq/L

Statistic analysis

Geochemical evolution river water analysis (Piper trilinear diagram triangle) using Grapher software (Piper, 1944).

RESULTS AND DISCUSSION

The water quality of the river is deteriorated mainly by natural processes and through anthropogenic activities like the discharge of industrial sewage, domestic wastewater and agricultural drainage water to the river (Singh and Kumar, 2017). However, the main pollutants for river pollution are the industrial sewages, domestic wastewater and agricultural drainage water (Jarvie *et al*. 1998; Barakat *et al*. 2016). Since river is the main resource of freshwater to human beings for use in different purposes, it is wise to protect and control the rivers from pollution and to have reliable information on water quality for effective management. Therefore, regular monitoring and evaluation of the water quality are required to protect, control and manage the river water from deterioration (Singh et al. 2005; Barakat *et al*., 2016).

Water quality generally encompasses the physical, chemical, biological, radiological and aesthetic characteristics of the water (Abdul *et al*. 2010; Ombaka and Gichumbi 2012). The evaluation of water quality of freshwater is essential because of the extreme demand and vulnerability to pollution in developing countries and also for the concern of being diminished in the near future (Ongley 2000; Yan *et al*., 2015). Water quality index (WQI) is a valuable and unique rating to depict the overall water quality status. It was initially developed by Horton in 1965. The present study carried out WQI and SAR of Pazhayar River in Kanniyakumari District, Tamil Nadu, India, during 2016 in selected places and seasons.

The spatial distribution of ions in Pazhayar river, Kanniyakumari district, Tamil Nadu, India - 2016

The spatial distribution of anions and cations in the study area were also used to compute then water types of the river water system at various locations in Pazhayar river, Kanniyakumari district, Tamil Nadu, India. The converted values were plotted into the piper trilinear diagrams (Piper, 1944) and Sodium absorption ratio (Richard, 1954) in order to decipher the potability, water types and classes of the river surface waters in Pazhayar river, Kanniyakumari district.

Piper diagram is extensively used to understand problems concerning the geochemical evolution of river surface water. This diagram consists of three distinct fields including two triangular fields and a diamond-shaped field. The cations expressed as a percentage of total cations in meq/l as a single point on the left triangle while anions plot in the right triangle

(Piper 1944). Each point is then projected into the upper field along a line parallel to the upper margin of the field and the point where the extension intersects indicates the character of the water as represented by the relationship among Na^+, K^+, Ca^{2+}, Mg^{2+}, $CO3^-$ + $HCO3^-$, Cl^- and $SO4^{2-}$ ions.

A Piper diagram is a simple and widely used method for determining the type of river surface water (Wu *et al.,* 2018; Li *et al.,* 2016). In this study, a Piper diagram was obtained by using the Grapher software. As shown in references figure 1, a Piper triangle consists of a diamond and two triangles, in which the diamond is divided into six (6) regions. The diamond shows the general hydrochemical characteristics of the water sample, while the triangle shows the relative content of each ion.

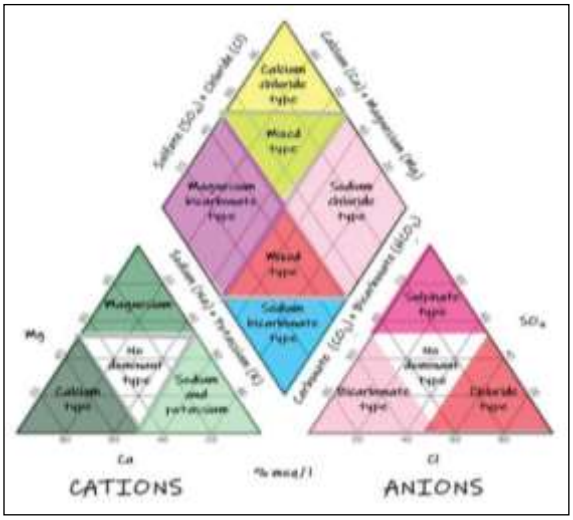

Figure 1: Piper trilinear diagram result observation (Sources: Ogbozige and Toko, 2020)

Table 2: The spatial distributions of the anions and cations (mEq/L) of the pre-monsoon surface water in Pazhayar river, Kanniyakumari district, Tamil Nadu, India - 2016

Pre-monsoon										
Station		**Cations (+)**				**Anions (-)**			**pH**	**TDS** (mg/L)
ID	**Place**	**Ca (mEq/L)**	**Na (mEq/L)**	**K (mEq/L)**	**Mg (mEq/L)**	**Cl (mEq/L)**	**SO_4 (mEq/L)**	**HCO_3 (mEq/L)**		
S1	Puthery	14.55	80.869	1.38	58.84	11.58	1.45	3.49	8.2	1830
S2	Ozhuginasery	12.80	94.34	1.43	60.16	12.68	1.39	5.23	7.6	3100
S3	Kothaigramam	13.85	86.08	1.30	65.34	13.02	1.16	5.24	7.6	2130
S4	Suchindram	12.40	74.34	1.25	63.62	15.53	1.31	3.65	7.8	2150
S5	Kakkamur south	11.55	443.47	1.53	66.74	22.28	1.20	3.67	7.1	2600
S6	Thamaraikulam north	13.30	495.65	1.71	74.89	22.14	1.39	5.12	8.2	2800
S7	Near the salt pan 2	14.60	505.21	1.71	70.86	22.42	1.39	3.47	8.1	2002

S8	Near the mangrove forest	12.65	519.21	1.56	72.42	30.76	1.72	1.90	7.7	2130
S9	Near the salt pan 1	12.90	527.82	1.53	64.11	50.53	1.66	1.81	7.9	2520
S10	Sea mouth	13.80	548.69	1.51	72.26	28.89	1.70	1.88	7.2	4940

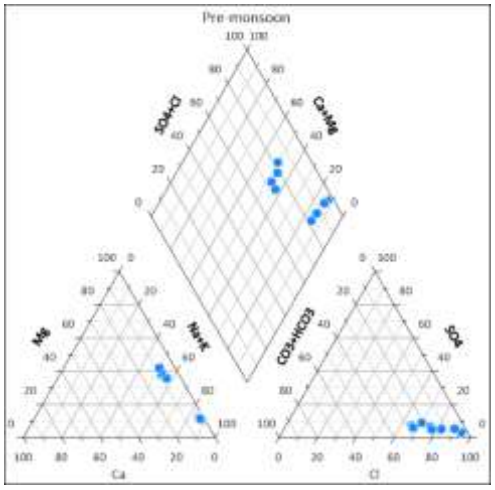

Figure 2: Piper trilinear diagram (% of mEq/L) in pre-monsoon surface water of Pazhayar river, Kanniyakumari district, Tamil Nadu, India - 2016

Most of station in Pazhayar river surface water samples belong to zones of Sodium chloride type in the diamond portion. For cations, most of water samples belong to zones of Sodium and Potassium type (left lower triangle portion). With respect to anions, most water samples chloride type, represent in figure 2, during pre-monsoon season. This indicates that the references to figure 1.

Table 3: The spatial distributions of the anions and cations (mEq/L) of the monsoon surface water in Pazhayar river, Kanniyakumari district, Tamil Nadu, India - 2016

Monsoon										
Station		**Cations (+)**				**Anions (-)**			**pH**	**TDS** (mg/L)
ID	**Place**	**Ca (mEq/L)**	**Na (mEq/L)**	**K (mEq/L)**	**Mg (mEq/L)**	**Cl (mEq/L)**	**SO_4 (mEq/L)**	**HCO_3 (mEq/L)**		
S1	Puthery	12.25	33.39	1.71	19.50	7.54	4.41	1.90	6.3	879
S2	Ozhuginasery	10.75	38.08	1.43	19.91	7.45	2.35	1.90	6.5	974
S3	Kothaigramam	10.4	42.52	0.87	20.16	8.81	4.87	1.98	6.8	781
S4	Suchindram	10.95	44.95	1.15	18.51	8.72	6.50	1.96	7.0	1060
S5	Kakkamur south	11.05	66.21	0.76	43.20	8.53	7.58	2.15	7.1	834
S6	Thamaraikulam north	12.35	46.43	0.74	50.53	10.28	8.37	2.09	7.1	2400
S7	Near the salt	11.35	44.56	1.02	51.11	8.81	8.66	2.12	7.2	967

	pan 2									
S8	Near the mangrove forest	12.55	622.39	1.15	50.86	10.67	6.50	2.13	7.2	2710
S9	Near the salt pan 1	11.05	613.04	0.82	50.53	19.46	1.35	1.90	7.3	1671
S10	Sea mouth	12.3	618.34	1.33	49.79	19.68	1.50	1.85	7.3	854

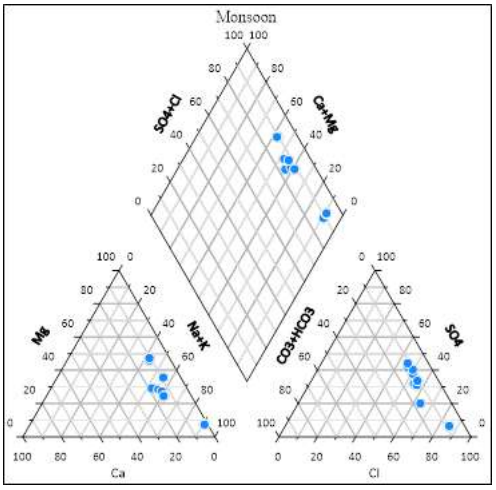

Figure 3: Piper trilinear diagram (% of mEq/L) in monsoon surface water of Pazhayar river, Kanniyakumari district, Tamil Nadu, India - 2016

Most of station in Pazhayar river surface water samples belong to zones Sodium chloride type in the diamond portion. For cations, most of water samples belong to zones Sodium and Potassium type (left lower triangle portion). With respect to anions, most water samples chloride type, represent in figure 3, during monsoon season. This indicates that the references to figure 1.

Table 4: The spatial distributions of the anions and cations (mEq/L) of the post-monsoon surface water in Pazhayar river, Kanniyakumari district, Tamil Nadu, India - 2016

Post-monsoon										
Station		**Cations (+)**				**Anions (-)**			**pH**	**TDS** (mg/L)
ID	**Place**	**Ca (mEq/L)**	**Na (mEq/L)**	**K (mEq/L)**	**Mg (mEq/L)**	**Cl (mEq/L)**	**SO_4 (mEq/L)**	**HCO_3 (mEq/L)**		
S1	Puthery	6.90	44.69	0.87	52.01	8.81	1.14	3.53	7.9	1513
S2	Ozhuginasery	7.10	47.34	1.10	52.26	9.71	1.12	2.54	7.8	1920
S3	Kothaigramam	7.15	54.86	1.41	51.76	7.57	0.95	2.06	8.1	1960
S4	Suchindram	7.10	53.78	1.43	48.31	12.88	1.37	2.08	7.8	1980
S5	Kakkamur south	5.85	51.04	1.15	44.27	16.01	1.10	2.27	7.8	520
S6	Thamaraikulam north	6.35	54.21	0.87	48.72	15.64	0.93	2.10	7.4	1200
S7	Near the salt pan 2	6.50	488.17	1.12	51.76	22.28	0.70	2.71	7.4	1400

S8	Near the mangrove forest	6.25	492.21	1.33	51.27	25.14	1.14	2.47	8.2	1510
S9	Near the salt pan 1	6.40	508.34	1.43	55.72	22.28	1.10	2.50	8.3	1670
S10	Sea mouth	6.25	526.82	1.41	50.94	28.89	1.14	2.36	7.8	1620

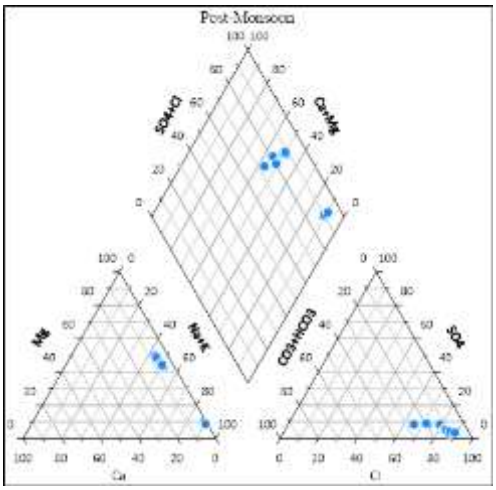

Figure 4: Piper trilinear diagram (% of mEq/L) in post-monsoon surface water of Pazhayar river, Kanniyakumari district, Tamil Nadu, India - 2016

Most of station in Pazhayar river surface water samples belong to zones Sodium chloride type in the diamond portion. For cations, most of water samples belong to zones Sodium and Potassium type (left lower triangle portion). With respect to anions, most water samples chloride type, represent in figure 4, during post-monsoon season. This indicates that the references to figure 1.

Water quality index calculation (WQI)

WQI is commonly used for the detection and evaluation of water pollution (Subba Rao, 1997; Magesh *et al.* 2013). The chemistry of river water is often used as a tool for discriminating the drinking and irrigation water quality (Subba Rao, 2006; Vasanthavigar *et al*. 2010).. WQI is defined as a technique of rating that provides the composite influence of individual water quality parameters on the overall water quality (Mitra and ASABE Member 1998). (World Health Organization 2011) standards for drinking water quality have been used to calculate the WQI. The relative weight (*wi*) was assigned for water quality parameters

based on their relative importance on water quality for drinking purposes (Table 6). The calculation of WQI for Pazhayar river water is shown in table 7.

Table 6: Relative weight of chemical of physico-chemical Parameters

Parameter	Weight (wi) (Vasanthavigar *et al.*, 2010)	Wi	WHO Standard (2011)
pH	4	0.153846	6.5 – 7.5
TDS (mg/L)	5	0.192308	500
HCO_3 (mg/L)	3	0.115385	500
Cl (mg/L)	3	0.115385	250
SO_4 (mg/L)	4	0.153846	250
Ca (mg/L)	2	0.076923	75
Mg (mg/L)	1	0.038462	50
Na (mg/L)	2	0.076923	200
K (mg/L)	2	0.076923	200
	n= 26	**Sum = 1**	

Table 7: Water quality index (WQI) in in Pazhayar River, Kanniyakumari district, Tamil Nadu, India – 2016

Station		Pre-monsoon		Monsoon		Post-monsoon	
ID	**Place**	**WQI**	**Classified water**	**WQI**	**Classified water**	**WQI**	**Classified water**
S1	Puthery	273.81	Very poor	150.25	Poor	200.78	Very poor
S2	Ozhuginasery	335.14	Unsuitable	149.13	Poor	219.58	Very poor
S3	Kothaigramam	297.22	Very poor	154.68	Poor	223.81	Very poor
S4	Suchindram	285.65	Very poor	172.62	Poor	229.65	Very poor
S5	Kakkamur south	640.41	Unsuitable	208.78	Very poor	168.90	Poor
S6	Thamaraikulam north	710.35	Unsuitable	266.11	Very poor	200.46	Very poor
S7	Near the salt pan 2	684.96	Unsuitable	206.96	Very poor	606.61	Unsuitable
S8	Near the mangrove forest	711.07	Unsuitable	784.23	Unsuitable	621.01	Unsuitable
S9	Near the salt pan 1	758.78	Unsuitable	731.16	Unsuitable	641.51	Unsuitable
S10	Sea mouth	843.19	Unsuitable	707.80	Unsuitable	660.83	Unsuitable

Note: Type of water based on water quality Range: i) <50 Excellent water; ii) 50–100 Good water; iii) 100–200 Poor water; 200–300 Very poor water and >300 Water unsuitable for drinking purposes.

According to the above WQI values at various stations and seasons (Table 7), there was an increasing trend in WQI values along the downstream, indicating an increase in the Pazhayar River's pollution load. Pollution load increases in rivers due to effluent discharges by small-scale industries, municipal waste, etc. The Pazhayar River's WQI is unsuitable in all stations and seasons. Similarly, AL-Obaidi *et al.,* (2020) reported the Tigris River is very poor quality and that the most effective parameters in WQI are physic-chemical parameters.

Sodium Adsorption Ratio (SAR)

River water quality can also determine the suitability for irrigation, because high levels of ions in water can affect plant growth (Nematollahi *et al.,* 2016). In order to determine the quality of the Pazhayar River surface water for agricultural irrigation purposes, SAR of irrigation water quality, represented in table 5. The present study concluded that the monsoon and post-monsoon season of Pazhayar river surface water is suitable for irrigation purposes.

Table 5: River water quality determine the suitability for irrigation based on SAR (Richard, 1954) in Pazhayar River, Kanniyakumari district, Tamil Nadu, India - 2016

Station		Pre-monsoon		Monsoon		Post-monsoon	
ID	**Place**	**SAR**	**Classified water**	**SAR**	**Classified water**	**SAR**	**Classified water**
S1	Puthery	13.34	Good	8.37	Excellent	8.23	Excellent
S2	Ozhuginasery	15.62	Good	9.72	Excellent	8.69	Excellent
S3	Kothaigramam	13.68	Good	10.87	Good	10.10	Good
S4	Suchindram	12.05	Good	11.71	Good	10.21	Good
S5	Kakkamur south	70.87	Poor	12.71	Good	10.19	Good
S6	Thamaraikulam north	74.63	Poor	8.28	Excellent	10.33	Good
S7	Near the salt pan 2	77.28	Poor	7.97	Excellent	90.44	Poor
S8	Near the mangrove forest	79.60	Poor	110.53	Poor	91.77	Poor
S9	Near the salt pan 1	85.05	Poor	110.47	Poor	91.21	Poor
S10	Sea mouth	83.64	Poor	110.97	Poor	98.51	Poor

Note: Classified water standard for irrigation based on sodium absorption ratio i) 0-10 Excellent; ii) 10-18 Good; iii) 18-28 Fair and >28 Poor.

The river water analysis of the physical, chemical and biological parameters is essential to control and estimate the most effective parameters on Pazhayar river surface water quality, which need to monitor and control pollution sources such as municipal and industrial wastewater discharges. The investigating of SAR values is imperative because of

their effects on water quality for irrigation purposes and their significant impact on the infiltration rate of the soil (Aboukarima *et al.,* 2018; AL-Obaidi *et al.,* 2020). The high concentration of Sodium in irrigation water increases the salinity of the water that affects soil classification and conversion from natural to saline water, thereby reducing hydraulic conductivity and infiltration rate of soil (Saha *et al.,* 2017; AL-Obaidi *et al.,* 2020). Predicting the effect of SAR is considered essential for river water quality, irrigation and agricultural. The concentration of SAR in the river can be influenced by many physicochemical parameters, the rate of discharge water into the river and many other processes occurring at the upstream location, in addition, the increase in SAR value in the water quality of irrigation leads to the undesirability of water by Weiner, (2013). SAR concluded in our study that all seasons are suitable for stations 1 to 4, but the surface of the Pazhayar River is undesirable for stations 8 to10. SAR prediction tool that can be used effectively to describe the suitability of river water quality for irrigation purposes by AL-Obaidi *et al.,* (2020).

CONCLUSION

Thus, the study concluded that the monsoon and post-monsoon seasons of Pazhayar river surface water are suitable for irrigation purposes in stations 1 to 6, but unsuitable for drinking purposes in all stations and seasons for human use. The most of the station and all season in Pazhayar river surface water respect to sodium chloride type ions.

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