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Original Article

Assessment of Hydrochemistry by Using Geo-Spatial Technology in Padmanabham Mandal, Visakhapatnam District, Andhra Pradesh-India

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Abstract

Groundwater is an important natural resource for sustaining life. The present study mainly focuses on the assessment of hydrochemistry of groundwater at three piezometric head locations of bore wells in Padmanabham Mandal Visakhapatnam District by using Weighted Arithmetic Method of the Water Quality Index (WQI)along with Inverse Distance Weighting (IDW) in GIS to show the spatial distribution of water quality parameters. The groundwater sample datasets of post-monsoon from 2019to 2023and pre-monsoon from 2019 to 2023 were collected. Physio chemical parameters like cations and anions are analysed. WQI indices used are Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), Sodium Concentration (Na%), Kelly's Ratio (KR), Magnesium Ratio (MR), and Permeability Index (PI). The results from the study shows that the high pH value in both seasons, EC values are in the range of 1137-2340 µs/cm in pre-monsoon season whereas in post-monsoon season is 1105-2500 µs/cm are classified as a permissible to doubtful class. The average value of the WQI's in Ananthavaram (62.73), Ayinada (54.41) and Pandrangi as (69.58) are classified as a poor class in pre-monsoon where as in post-monsoon in Ananthavaram (43.04), Ayinada (47.99) are classified as good class, and in Pandrangi (92.35) classified as very poor class.

Keywords: ***GIS, Hydrochemistry, Inverse Distance Weighting (IDW), Weighted Arithmetic Method of Water Quality Index (WQI).***

Introduction

Groundwater is an important natural resource that is found practically everywhere beneath the surface of the planet in thousands of small aquifer systems with comparable properties rather than in a single, extensive aquifer. When surface water is short, groundwater serves as a critical backup which helps in supporting industrial, agricultural and human needs. India is home to 16.6% of the world's population, 2.2% of worlds land and 4% of their water resources. Around 2.5 billion people on the planet only use readily available groundwater for irrigation and household requirements (Pradeep et al., 2024).

Currently, groundwater is decreasing at a rate of 800 km^3 per year worldwide. Recent studies have shown that almost 20% of worldwide groundwater is utilized for irrigation (Adimalla et al., 2018). the groundwater used for irrigation is app. 245 × 10^9 m^3 (CGWB 2014). In India annual groundwater usage is app. 230 ×$10^9 m^3$, and the largest user of groundwater worldwide is India (Dimple et al., 2022).

Groundwater has been used as an alternative to freshwater for different irrigation systems (Geophry et al., 2024). Ground water has become the major source of water use in the agricultural sector, in many countries because of insufficient river and drainage systems. Therefore, poor ground water quality is a matter of worry in recent years (Kishan et al., 2018).

Groundwater quality depends on the nature of recharging water, precipitation, subsurface and surface water and hydro-geochemical processes in aquifers, land-use/land-cover change. Temporal changes in the constitution and origin of the water recharge, and the human factor, frequently cause periodic changes in groundwater quality. Groundwater quality degrades in twofold, first, due to geochemical reactions in the aquifers and soils and, second, time when it is supplied through improper canals/drainages (Nadia et al., 2020).

The objective of the study is to identify hydro chemical characteristics of groundwater in the area and to evaluate its suitability for irrigation purposes in the area of the Padmanabham Mandal Visakhapatnam District so that the best use of groundwater could be done for irrigation purposes.

Assessment of quality of groundwater is done in the study area because of improper planning for the disposal of house hold contaminants, sewage disposal system leaks or disposing directly into open area and into river, animal wastes, chemical disposals and development of agri-industries that requires more water. This study was carried out in a way to collect groundwater samples data during pre-monsoon and post-monsoon seasons. Weighted Arithmetic Method of the Water Quality Index, hydro chemical parameters and indices such as Na%, SAR, RSC, PI, MR, KR, and Cl^-, HCO_3^-, Mg^{2+}, Ca^{2+} Na^+ and K^+ were used to analyse quality. Hydro chemical characterization was also done based on BIS Standards to understand the groundwater quality. Also, spatial distribution maps were plotted using the IDW technique in Arc GIS Pro. For preparation of thematic maps and to extract the boundary file Survey of India topographical maps of the series 65 O/1, 65 O/5, 65 N/4, and 65 N/8 with a scale 1:50000 have been used.

Materials And Methods

1. Study Area

The study area Padmanabham Mandal is located in Visakhapatnam District of Andhra Pradesh - India and bounded by $17^{0}59^{'}40”$ North latitude and $83^{0}33’53”$ East longitude, covering an area of 137.12 km^2. It is bounded by Bheemunipatnam towards the south, Jami Mandal towards the west, and Bhogapuram Mandal towards the east in Vizianagaram district. Gostani river flows through this area stretching nearly 120 km. There are about 25 Revenue Villages and 22 Gram Panchayats in Padmanabham Mandal. As per 2011 census the total population of the Mandal was 52,079, and has a population density of 347.5 inhabitants per square kilometre. There are about 13,274 houses in the sub-district. The climate of this region is tropical wet and dry climate. The temperature varies from 24.47 ^oC to 31.93 ^oC. The location of the study area is shown in the Fig-1. In the study area major occupied soil types are clayey and silty soils. The principal crop grown is paddy and also major crops are groundnuts, vegetables, fruits and plantations like eucalyptus, teak and mango.

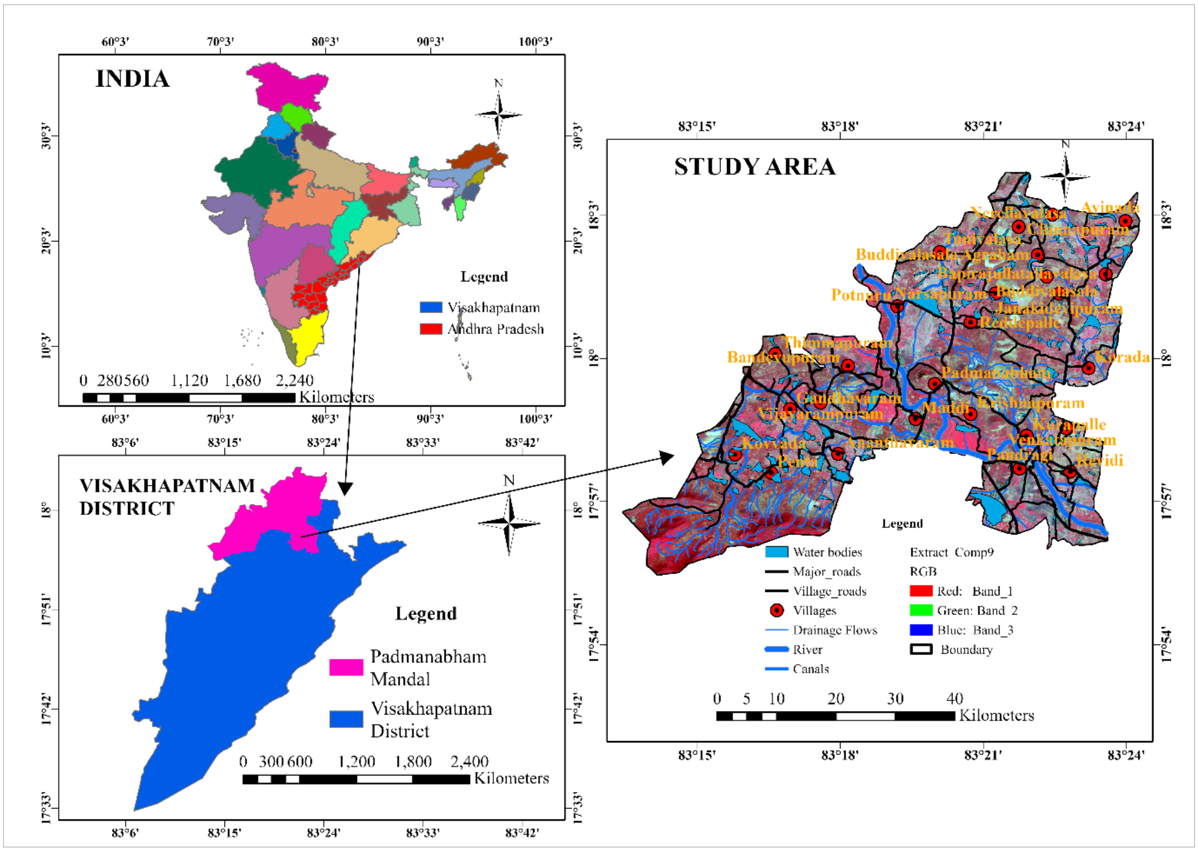

Fig-1: Location map of Padmanabham Mandal in Visakhapatnam District, AP.

2. Methods

The data related to groundwater quality have been acquired from Andhra Pradesh (AP) Ground Water and Water Audit Department in Visakhapatnam District Andhra Pradesh-India during pre-monsoon and post-monsoon seasons for 5 years. The data was collected through Piezometric level heads present in the study area. Totally, at 3 locations (Ananthavaram (L1), Ayinada (L2), Pandrangi (L3)) we have Piezometric instruments in the study area from 2019, so the head levels for pre-monsoon and post-monsoon of 5 years has been collected initially. An evaluation of ground water quality was conducted through comprehensive physicochemical analysis and its characteristics are done based on BIS standards (Table-1). The resulting data were then employed to compute relevant irrigation quality indices such as Sodium Percentage (% Na), Kelly's Ratio (KR), Sodium Adsorption Ratio (SAR), Permeability Index (PI), Residual Sodium Carbonate (RSC), and Magnesium Ratio (MR).

2.1 Method to calculate Water Quality Index (WQI) of groundwater

The WQI was established by Horton (1965) and subsequently developed by Brownetal.,1970. The indices-based approach considered in the current study was the Weighted Arithmetic Method of the WQI. Weight Arithmetic WQI is an effective criterion having several advantages, including addressing issues in general water quality information to the policymakers and citizens, requiring fewer parameters, reflecting the cumulative influence of different parameters essential for water quality inspection, and describing the suitability of its sources. The Weight Arithmetic Water Quality

Index framework is generally used in India (Geophry Wasonga Anyango et al., 2024).

The weighted arithmetic index approach used to calculate the WQI includes calculation of:

Unit weight for each parameter, $Wn = \frac{k}{Sn}$ (1)

Where k is the proportionality constant, which is derived by: $k = \frac{1}{\sum \frac{1}{Sn=1,2,3....n}}$

Sn = Standard desirable value of the nth parameters

On summation of all selected parameters unit weight factors, Wn = 1(unity)

Quality rating, $Qn = \left(\frac{Vn-Vi}{Sn-Vi}\right) X100$ (2)

Vn = observed parameter's actual value.

Vi = parameter's ideal value. Except for pH (Vi=7), Vi=0 for remaining parameters.

Finally we calculate $WQI = \frac{\sum QnWn}{\sum Wn}$ (3)

WQI values calculated for each location of 5 years and its characterisation are shown in the table-2.

2.2 Individual indicators for Water Quality of Groundwater: Groundwater is widely used for irrigation in the study area. The quality of irrigation water is areflection of its mineral composition and its effect on plants and soil. Therefore, a water quality assessment for irrigation is very important for thriving agricultural production. The descriptive statistics of parameters such as SAR, RSC, Na%, KR, PI, and MH were calculated to determine the suitability of the study area's groundwater quality for irrigation.

A. Sodium Adsorption Ratio:

SAR = $Na^+ / \sqrt{[(Ca^{2+} + Mg^{2+})/2]}$

B. Residual sodium carbonate:

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

C. Sodium Percentage (Na%):

Na% = $[(Na^+ + K^+) / (Na^+ + Ca^{2+} + Na^+ + K^+)] * 100$

D. Kelly's Ratio:

KR = $Na^+ / (Ca^{2+} + Mg^{2+})$

E. Magnesium Ratio:

MR = $[Mg^{2+} / (Ca^{2+} + Mg^{2+})] * 100$

F. Permeability Index:

PI = $(Na^+ + \sqrt{HCO_3^-}) *100 / (Ca^{2+} + Mg^{2+} + Na^+)$

The values obtained after calculating each parameter by using the above formulas along with its class for pre-monsoon and post-monsoon seasons are represented in table-3.

Results and Discussions

Table 1: BIS standards for seasonal wise concentrations of ions in groundwater samples for irrigation purpose according to IS:10500-1991 along with the values in the ranges obtained for pre-monsoon and post-monsoon seasons in the study area.

S. No	Constituents	BIS standards	Pre-monsoon value ranges			Post-monsoon value ranges		
			L1	L2	L3	L1	L2	L3
1	pH	6.5-8.5	7.8-9.0	7.8-9.4	8.3-8.9	7.7-9.0	7.5-8.6	8.3-9.0
2	EC	400 µs/cm	1137-2000	1852-2340	1170-1420	1105-1865	1286-2500	1217-1320
3	TDS	500 mg/l	728-1280	1185-1498	749-909	707-1194	823-1600	779-845
4	TH	300 mg/l	280-520	420-600	260-420	180-340	200-440	320-500
5	Ca^{2+}	75 mg/l	48-160	64-128	32-88	16-72	16-96	16-108
6	Mg^{2+}	30 mg/l	4.9-97.2	38.9-107	9.7-68.1	24.3-63.2	19.4-48.6	43.8-77.79
7	Na^+	200 mg/l	93.7-245	190-270.4	77.9-180.9	125-270.7	140.3-284.3	73.9-135
8	K^+	75 mg/l	7.8-139	0.8-55.2	0.7-100.5	22.7-102.6	53.5-154.2	1.25-4.74
9	HCO_3^-	200 mg/l	180-280	200-320	180-260	180-345	85-280	100-190
10	CO_3^{2-}	100 mg/l	0-140	0-200	60-80	0-140	0-80	20-140
11	F^-	1 mg/l	0.22-0.98	0.18-0.83	0.35-0.84	0.15-0.59	0.16-0.64	0.52-1.13
12	Cl^-	250 mg/l	95-285	238-450	124-180	86-270	143-484.5	100-190
13	NO_3^-	50 mg/l	0.68-27.43	20-33.09	5.2-24.50	4.5-24.0	13.2-36.7	4.7-16.2
14	SO_4^{2-}	400 mg/l	10.9-280	130.1-186.4	57.4-153.2	103.5-195.4	77-450	57-144.2

Table-2: Water Quality values and its characterizations at 3 locations in the study area for 5 years.

Season	Parameter	2019	2020	2021	2022	2023
In Pre-monsoon	**WQI value obtained in L1**	74.38	46.91	94.62	37.26	57.37
	Characterization	Very Poor to use	Good to use	Very Poor	Good to use	Poor to use
	WQI value obtained in L2	50.65	45.83	40.07	41.82	89.39
	Characterization	Poor to use	Good to use	Good to use	Good to use	Very Poor to use
	WQI value obtained in L3	84.88	70.81	84.57	45.43	59.06
	Characterization	Very Poor to use	Poor to use	Very Poor to use	Good to use	Poor to use
	WQI value obtained in L1	28.54	63.56	26.37	36.79	57.45
	Characterization	Good to use	Poor to use	Good to use	Good to use	Poor to use

In Post-monsoon	**WQI value obtained in L2**	49.59	46.74	40.89	29.86	68.83
	Characterization	Poor to use	Good to use	Good to use	Good to use	Poor to use
	WQI value obtained in L3	110.89	72.13	79.09	99.78	97.27
	Characterization	Unfit for Consumption	Poor to use	Very Poor to use	Very Poor to use	Very Poor to use

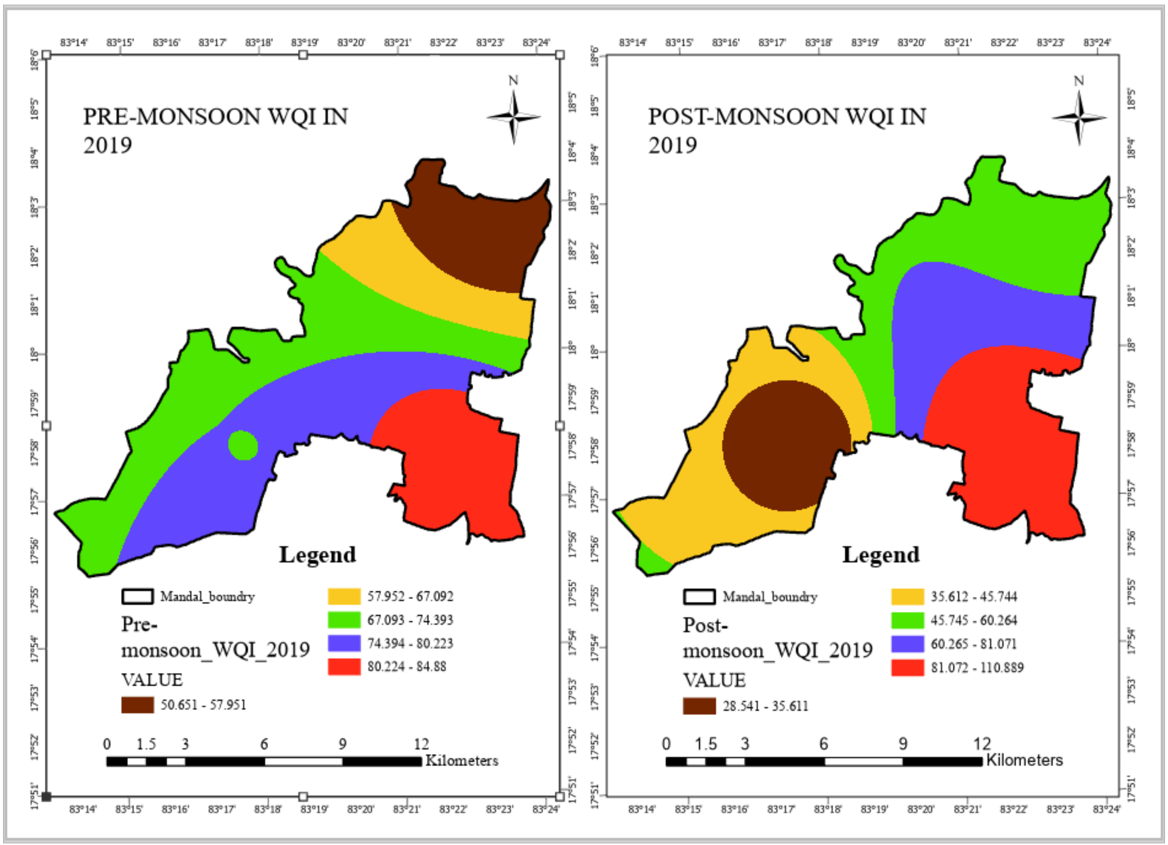

Fig-2: Spatial distribution of WQI values for pre-monsoon and post-monsoon in the 2019

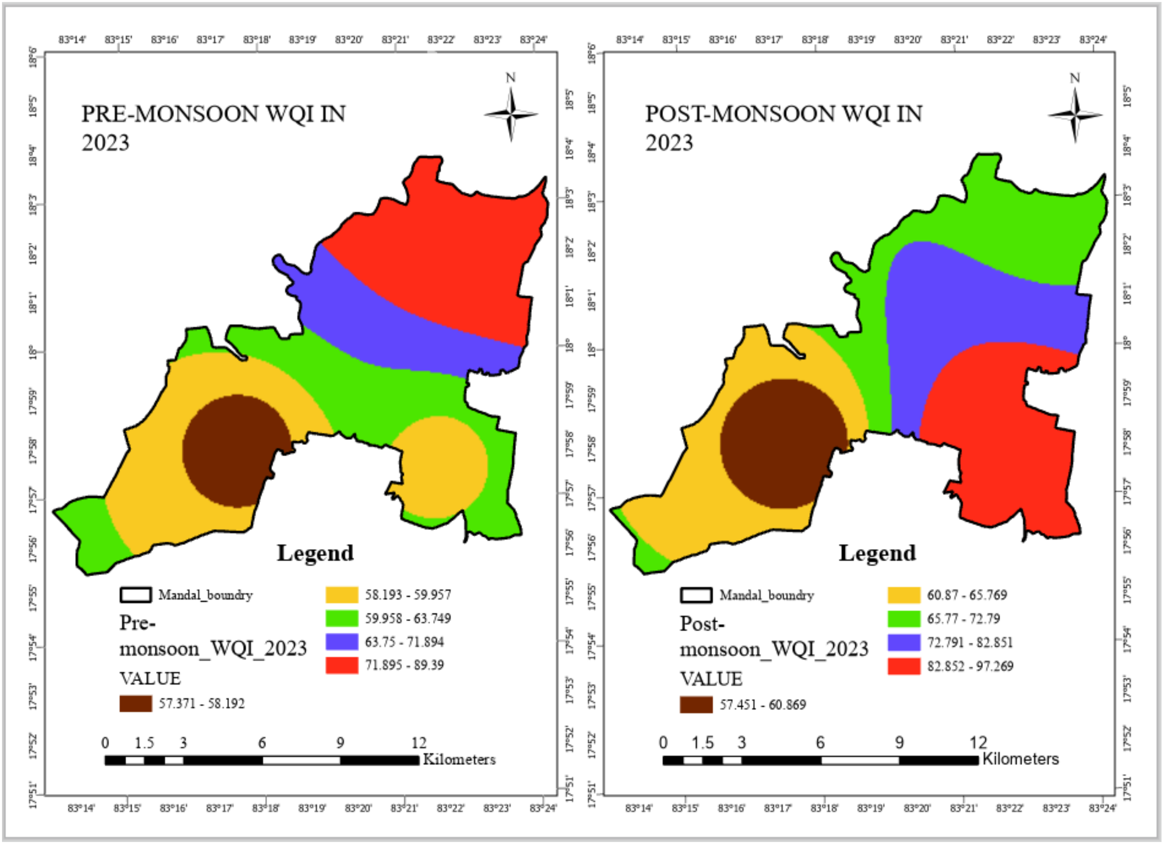

Fig 3: Spatial distribution of WQI values for pre-monsoon and post-monsoon in the 2023

Table-3: Shows the classification of the individual parameter values at each location for 5 years.

Season	Indices	2019			2020			2021			2022			2023		
		L1	L2	L3	L1	L2	L3	L1	L2	L3	L1	L2	L3	L1	L2	L3
Pre-monsoon	SAR	3.7	4.2	1.6	5.0	5.3	4.0	2.2	3.7	3.7	6.3	5.4	3.4	2.3	4.3	4.5
	Class	excellent	excellent	excellent	excellent	excellent	excellent	excellent	excellent	excellent	excellent	excellent	excellent	excellent	excellent	excellent
	RSC	-4.2	-4.8	-3.5	0.4	-1.2	1.3	1.1	-5.5	-0.9	2.3	2.5	1.6	-5.5	-7.4	-0.3
	Class	excellent	excellent	excellent	excellent	excellent	Suitable	excellent	excellent	excellent	Suitable	Suitable	Suitable	excellent	excellent	excellent
	KR	0.8	0.9	0.3	1.4	1.3	1.2	0.6	0.9	1.0	1.9	1.3	1.0	0.6	0.9	1.3
	Class	suitable	suitable	suitable	unsuitable	unsuitable	unsuitable	suitable	suitable	unsuitable	unsuitable	unsuitable	unsuitable	suitable	suitable	unsuitable
	PI	53.83	57.90	43.03	73.43	68.18	71.22	56.99	57.45	65.56	76.64	66.69	70.35	49.28	56.56	69.94
	Class	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	good	Fair	Fair	Fair	Fair	Fair
	Na %	45.36	48.76	28.72	66.98	56.46	54.68	39.62	51.20	51.48	66.91	58.68	60.69	40.53	48.47	57.46
	Class	Permissible	Permissible	good	Doubtful	Permissible	Permissible	good	Permissible	Permissible	Doubtful	Permissible	Doubtful	Permissible	Permissible	Permissible
	MH	77.14	68.29	66.96	53.65	47.92	57.45	35.61	33.62	75.22	14.41	43.78	15.52	4.85	73.59	40.33
	Class	unsuitable	unsuitable	unsuitable	unsuitable	suitable	unsuitable	suitable	suitable	unsuitable	suitable	suitable	suitable	suitable	unsuitable	suitable
Post-monsoon	SAR	4.0	5.3	3.3	3.7	5.9	2.7	4.6	7.6	2.9	6.8	6.3	3.1	5.6	3.7	1.4
	Class	excellent	excellent	excellent	excellent	excellent	excellent	excellent	excellent	excellent	excellent	excellent	excellent	excellent	excellent	excellent
	RSC	1.3	-4.4	-2.8	-1.6	-4.3	-1.5	-0.5	0.4	-1.3	2.0	0.8	0.2	-1.2	-2.0	-4.0
	Class	Suitable	excellent	excellent	excellent	excellent	excellent	excellent	excellent	excellent	Suitable	excellent	excellent	excellent	excellent	excellent
	KR	1.5	1.3	0.9	1.0	1.2	0.7	1.3	2.7	0.8	1.9	2.2	0.8	1.5	1.1	0.3
	Class	unsuitable	unsuitable	suitable	unsuitable	unsuitable	suitable	unsuitable	unsuitable	suitable	unsuitable	unsuitable	suitable	unsuitable	unsuitable	suitable
	PI	78.94	66.98	57.95	66.51	68.37	59.80	73.70	81.81	60.68	76.38	80.31	57.26	73.93	63.07	38.02
	Class	good	Fair	Fair	Fair	Fair	Fair	Fair	good	Fair	good	good	Fair	Fair	Fair	Fair
	Na %	68.81	57.27	47.79	55.69	64.69	42.21	63.07	76.51	43.96	67.03	75.73	44.82	63.45	57.74	24.38
	Class	Doubtful	Permissible	Permissible	Permissible	Doubtful	Permissible	Doubtful	Doubtful	Permissible	Doubtful	Doubtful	Permissible	Doubtful	Permissible	good
	MH	55.86	50.31	81.44	47.38	45.76	50.34	46.96	80.20	82.53	86.81	40.24	89.01	59.12	55.89	46.31
	Class	unsuitable	unsuitable	unsuitable	suitable	suitable	unsuitable	suitable	unsuitable	unsuitable	unsuitable	suitable	unsuitable	unsuitable	unsuitable	Suitable

Evaluation of hydro chemical parameters against BIS guidelines reveals concerning deviations from recommended standards. From table-1 we analysed that the physio chemical parameters: pH is crossing the standard limits in both seasons, EC values obtained in my study area are in the range 1137-2340 µs/cm in pre-monsoon whereas in post-monsoon season are in the range 1105-2500 µs/cm are classified as a permissible to doubtful class according to the BIS standard ranges for irrigation purposes. The WQI values obtained are shown in table-2, the average value of the WQI's obtained in Ananthavaram as 62.73, in Ayinada as 54.41 and in Pandrangi as 69.58 are classified as a poor class in pre-monsoon season where as in post-monsoon season, in Ananthavaram as 43.04, in Ayinada as 47.99 are classified as good class, and in Pandrangi as 92.35 is classified as very poor class. Theindividual indicators for Water Quality are shown in table-3. The KR values of pre-monsoon season in Ananthavaram as 1.06, in Ayinada as 1.05 and in Pandrangi as 1.00 are classified as an unsuitable class whereas in post-monsoon season, in Ananthavaram as 1.45, in Ayinada as 1.74 are classified as unsuitable and in Pandrangi as 0.70 is classified as a suitableclass. The Na% values of pre-monsoon season in Ananthavaram as 51.88%, in Ayinada as 52.71% and in Pandrangi as 5.060% are classified as permissibleclass whereas in post-monsoon season, in Ananthavaram as 63.61%, in Ayinada as 66.39% are classified as doubtful class and in Pandrangi as 40.63% is classified as permissibleclass. The MR values in pre-monsoon season in Ananthavaram as 37.13 is classified as suitableclass, in Ayinada as 53.44, in Pandrangi as 51.09 are classified as unsuitable class whereas in post-monsoon season in Ananthavaram as 59.22, in Ayinada as 54.48, in Pandrangi as 69.93 are classified as unsuitableclass. The PI values in pre-monsoon season in Ananthavaram as 62.03, in Ayinada as 61.36, in Pandrangi as 64.024 are classified as fair class and in post-monsoon season, in Ananthavaram as 73.89, in Ayinada as 72.11, in Pandrangi as 54.74 are classified as fair class. The SAR values obtained from pre-monsoon in Ananthavaram as 3.93, in Ayinada as 4.63 and in Pandrangi as 3.48 are classified as excellent class where as in post-monsoon season in Ananthavaram as 4.91, in Ayinada as 5.75, in Pandrangi as 2.67 are classified as excellent class. The RSC values in pre-monsoon season in Ananthavaram as -1.17, in Ayinada as -3.28, in Pandrangi as -0.35 are classified as excellent classand in post-monsoon season, in Ananthavaram as 0.02, in Ayinada as -1.90, in Pandrangi as -1.89 are classified as excellentclass to use for irrigation purposes.

Conclusions

The WQI values in pre-monsoon season are classified as poor class whereas in post-monsoon season in Ananthavaram and Ayinada are classified as good class but Pandrangi is classified as very poor class. The sufficient rainfall in post-monsoon season decreases the concentration levels from pre-monsoon to post-monsoon season. Individual Indicator values of KR are classified unsuitable class, Na% as permissible class, MR as unsuitable class, PI as fair class in pre-monsoon whereas in post-monsoon season KR as unsuitable class, Na% as doubtful class, MR as doubtful class, PI as fair class to use for irrigation purposes. At present we observe that SAR and RSC values are within the standard permissible limits that are suitable to use in both pre-monsoon and post-monsoon seasons.

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