Full Length Research Article

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Research Journal of Agricultural Sciences
Volume 15; Issue 03 (May–Jun 2024); pp 709–714

ISSN: 0976-1675 (P)
ISSN: 2249-4538 (E)

Evaluation of Water Quality Index (WQI) of Water Resources at Padre Village, Kasaragod Using GIS

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Received: 23 Feb 2024; Revised accepted: 30 Apr 2024

Abstract

In this paper, the estimation of water quality index (WQI) and hydro chemical analysis by statistical methods was carried out in the Padre microwatershed Kasaragod Kerala. WQI was calculated in order to find out the deviation in the water quality parameters particularly with respect to BIS permissible limits. Total 30 locations were selected of which samples were collected from fourteen open wells and thirteen Surangam water and three combined Surangam and open wells for the hydrochemical analysis. The Water Quality Index (WQI) values accept the suitability of water for drinking purposes. The center portion and southeast region of Padre microwatershed shows the quality of water is suitable for drinking purposes with WQI ranging from 0 to 58 in the pre-monsoon season and 0 to 49 in the post-monsoon season. Only few open wells namely, OW3, OW4, OW5, OW6, OW7 and OW13 at the bottom of the hillocks unfit for the same. Due to fluoride content above the permissible limit, one Surangam S14 near the northeastern portion and during the post-monsoon period the highest WQI of 108. This shows that proper treatment is necessary before it use for drinking purposes. Moreover, these wells should be protected against the contamination caused due to the fertilizers from agricultural lands.

Key words: Suranga a horizontal tunnel in foot hills of laterite terrain*,* Water quality index

All around the world, groundwater is utilized for irrigation, domestic and industrial usage. Due to the rapid population growth and the accelerated rate of industrialization, the demand for fresh water has significantly increased rapidly. Human health is at risk from most agricultural advancement activities, particularly excessive fertilizer uses and unhygienic conditions. Almost 80% of all human diseases, according to the WHO, are brought on by water. Once contaminated, groundwater cannot have its quality restored by removing the pollutants at the source. Hence, assess the groundwater's quality and devise strategies for preserving it become very crucial. Open wells are the primary source of water for home and agricultural uses in the Kasaragod district's midlands. Open wells came in two shapes: round and rectangular. The physicochemical properties of water play a significant role in the operation of an ecosystem and its stability to support life forms. In Kerala's Kasaragod area, the Surangam traditional sustainable and agrarian water management system ensures a steady supply of water for habitations and agriculture. A Surangam is essentially a horizontal tunnel that is 30 to 40 meters long and excavated into the side of a laterite hill to collect subsurface water and use gravity to retrieve it. In laterite hillocks, there were several water sources, but a sustainable agricultural water gathering system was a unique characteristic of the laterite hillocks in this Surangam [1-3]. The other sources, which were ecologically distinct, included borewell, open wells, and minor streams. The majority of these water bodies today bear sinks for the waste discharge resulting in deterioration of water quality due to the rapid ageing of urbanization and industrialization.

MATERIALS AND METHODS

Open wells and Surangam's were identified in the research area. At microwatershed level, sampling locations were fixed randomly based on accessibility, terrain geology, populated settlement, well availability, etc. To avoid contamination from any sources during sample collection, transportation, and analysis enough care was taken. Padre microwatershed, draining nearly 10 sq. km of basin area placed between 12° 02′ 27″ N and 12° 47′ 35″ N latitudes and 74° 51′ 54″ E and 75° 25′ 25″ E longitudes, is enclosed with an area of 10 sq.km in the Kasaragod District in Kerala State. Padre is in the Enmakaje Panchayath of the Kasaragod district in Kerala State. Water samples were collected from located Suranga sources and some open wells were collected in 2liter polyethylene cans and the basic tests like temperatures pH were conducted in field in both pre-monsoon and post monsoon seasons. Physico-chemical parameters were studied in laboratory by Indian standards methods as suggested by the American Public Health Association (1995). The assessment of physiochemical parameters of water performed with the standard operating methods as specified by the American Public Health Association [4-5]. The analyzed parameters were correlated with Bureau of Indian Standards (BIS 2012). The physicochemical parameters such as pH, electrical conductivity

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Citation: Natesh A, Bhat AK. 2024. Evaluation of water quality index (WQI) of water resources at Padre village, Kasaragod using GIS. *Res. Jr. Agril. Sci*. 15(3): 709-714.

(EC), dissolved oxygen (DO), biochemical oxygen demand (BOD), total hardness (TH) as $CaCO_3$, calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+), iron (Fe^+), carbonate (CO_3^-), bicarbonate (HCO_3^-), chloride (Cl^-), sulphate (SO_4^{2-}), nitrate (NO_3^-) and fluoride (F^-) [7]. Environmental Engineering Laboratory of the Civil Engineering Department at the research Centre, N.M.A.M. Institute of Technology, Nitte were used for physiochemical analysis. (Fig 1) shows the water sampling locations map of Padre microwatershed.

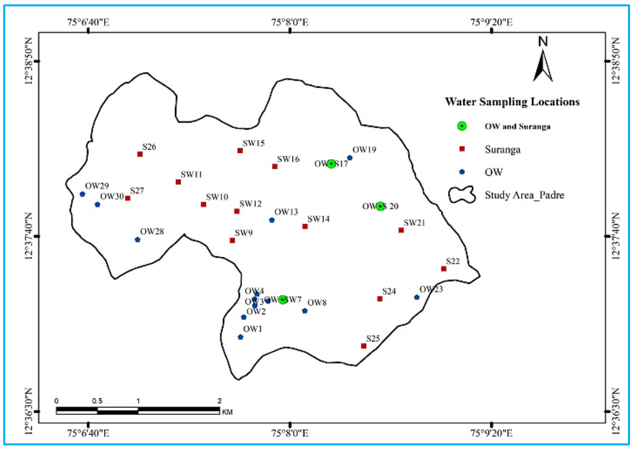

Fig 1 Sampling locations Map - Padre microwatershed

Statistical analysis

Statistical analysis has major role in the analysis of physico-chemical parameters in understanding the permissible limit of the variables and relationship between them [8]. Descriptive statistics, ANOVA two-factor without replication, and correlation matrix were performed using Excel 2009 [9].

Spatial interpolation method

Results were interpreted from the spatial variation maps and these maps were prepared using geostatistical analyst tool of ArcGIS 10.4 software. Inverse Distance Weighting (IDW) interpolation methods are commonly used by many authors [10]. The iso-variation maps were prepared for selected chemical parameters and for water quality index (WQI).

Water quality index (WQI)

The Water Quality Index Technique Using weighted average arithmetic is a method to evaluate the purity level of water based on its key factors. For domestic and drinking purposes, the quality of water is defined on Water Quality Index (WQI) [11]. Generally, physico-chemical attributes such as pH, EC, TDS, TH, alkali ($Na^+ + K^+$), Ca^{2+}, Mg^{2+}, Cl^-, HCO_3^-, NO_3^-, SO_4^{2-}, and F^- were used for this analysis. The selection of chemical parameters considered on their relevance in the Indian drinking water quality standard, [12]. A four-step method is used in the weighted mathematical Water Quality Index Method for computing the WQI of respective open wells and Suranga water samples. The unit weight (*Wi*) of each parameter is calculated using equation 1.1.

$$Wi = \frac{K}{Sn} \text{ .... (1.1)}$$

where Sn is the suggested standard value for the n^{th} parameter and K is the proportionality constant calculated using equation 1.2

$$K = \frac{1}{\Sigma\left(\frac{1}{Sn}\right)} \text{ .... (1.2)}$$

Brown *et al.* [13] calculated the value of qi (quality rating or sub-index) using equation 1.3.

$$qi = (Vo - Vi) * 100/(Sn - Vi) \text{ .... (1.3)}$$

Vo is the observed value; *Vi* is the ideal value (for pH it is 7 and rest are zero), and *Sn* is BIS (2012) permissible value of a particular parameter. Equation 1.4 used for the estimation of WQI

$$WQI = \Sigma \frac{qiWi}{\Sigma Wi} \text{ .... (1.4)}$$

The evaluation method of open well and suranga groundwater samples is shown in (Table 1). Five classes are identified based on WQI values, as shown in (Table 2).

Table 1 WQI evaluation - weighted arithmetic method

Parameter	Sn-standard	1/Sn	K=1/∑(1/Si)	Wi=K/Sn
Turbidity	5	0.20		0.05
EC	300	0.00		0.00
TDS	500	0.00		0.00
TH	300	0.00		0.00
Alkali	200	0.01		0.00
Ca^{++}	75	0.01		0.00
Mg^{++}	30	0.03	0.226541482	0.01
Cl	250	0.00		0.00
HCO_3	200	0.01		0.00
NO_3	45	0.02		0.01
SO_4	200	0.01		0.00
F	1.5	0.67		0.15
Fe	0.3	3.33		0.76
		4.41		1

Table 2 Drinking water quality classification based on WQI

Class	WQI range	Water quality status
A	<50	Excellent
B	50-100	Good
C	101-200	Poor water
D	201-300	Very poor water
E	>300	Water unsuitable for drinking

RESULTS AND DISCUSSION

A descriptive statistical summary of physicochemical parameters, such as the minimum, maximum, average, standard deviation (SD), and coefficient of variation (CV), for pre-monsoon (PRM), and post-monsoon (POM), was done for suranga water (SW) and open well (OW) samples. BIS (2012) standards used to correlate the obtained results and tabulated in (Table 3-4). Chemical parameters are denoted in mg/L, except for Turbidity in NTU, EC in µS/cm and pH in a number scale.

Table 3 Statistical summary of Surangam water (PRM & POM)

Standards		Suranga water (pre-Monsoon)					Suranga water (post Monsoon)				
Parameters	BIS (2012)	Min.	Max.	Mean	S. D	C V	Min.	Max.	Mean	S. D	C V
Temp °C		27.90	33.30	28.38	1.30	0.05	27.20	28.50	27.54	0.32	0.01
pH	6.5 - 8.5	4.56	6.80	5.59	0.85	0.15	4.56	6.90	5.62	0.85	0.15
EC	1500	18.00	34.00	26.24	6.26	0.24	22.00	44.00	33.56	8.12	0.24
TDS	500 - 2000	8.60	28.00	20.27	5.75	0.28	14.30	28.60	21.82	5.28	0.24
Turbidity	5 NTU	0.10	3.00	0.88	0.66	0.75	0.20	1.40	0.81	0.31	0.38

TH	200 - 600	0.80	23.60	4.27	5.38	1.26	1.29	28.07	5.00	6.49	1.30
Na^+	200	5.40	8.48	6.90	0.77	0.11	11.00	17.86	14.22	1.91	0.13
K^+	12	0.36	0.89	0.62	0.14	0.22	0.99	3.10	1.97	0.51	0.26
Ca^{++}	75 - 200	0.43	3.85	1.87	1.23	0.66	0.80	4.01	2.11	1.17	0.55
Mg^{++}	30 - 100	0.20	22.50	2.41	5.27	2.19	0.49	26.47	2.90	6.39	0.21
Fe+	0.3-1	0.00	1.40	0.09	0.34	3.61	0.00	0.38	0.03	0.10	3.27
Cl–	250 - 1000	8.10	22.10	15.45	4.32	0.28	6.00	18.00	13.25	3.92	0.30
HCO_3-	400	7.40	13.40	9.28	1.39	0.15	7.00	13.00	8.94	1.40	0.16
NO_3 -	45	0.00	0.00	0.00	0.00	ND	0.00	0.27	0.09	0.10	1.14
SO_4 -	200 - 400	0.00	1.80	0.11	0.44	4.12	0.00	2.90	0.18	0.73	4.00
F -	1-1.5	0.00	0.50	0.03	0.12	4.12	0.02	1.41	0.72	0.48	0.67

Table 4 Statistical summary of open well (PRM & POM)

Standards		Open well (Pre-monsoon)					Open well (Post-monsoon)				
Parameters	BIS (2012)	Min.	Max.	Mean	S. D	C V	Min.	Max.	Mean	S. D	C V
Temp °C		28.00	33.40	30.48	1.87	0.06	28.00	29.30	28.51	10.04	0.35
pH	6.5 - 8.5	4.76	6.63	5.71	0.62	0.11	4.76	6.70	5.78	1.65	0.29
EC	1500	29.00	148.00	61.83	33.01	0.53	21.00	139.00	48.54	35.23	0.73
TDS	500 - 2000	8.90	52.30	21.70	13.11	0.60	14.10	90.35	31.58	22.87	0.72
Turbidity	5 NTU	0.10	42.30	5.41	12.14	2.24	0.20	77.80	9.22	20.05	2.17
TH	200-600	1.75	22.30	5.92	5.51	0.93	1.29	21.06	5.13	5.10	0.99
Na^+	200	9.14	12.10	10.54	0.82	0.08	2.16	4.60	3.02	1.20	0.40
K^+	12	0.87	1.52	1.07	0.21	0.19	0.99	3.10	1.97	0.51	0.26
Ca^{++}	75 - 200	1.10	16.20	4.33	4.01	0.93	0.80	15.23	3.76	3.69	0.98
Mg^{++}	30 - 100	0.51	6.10	1.58	1.56	0.98	0.40	5.83	1.38	1.46	1.06
Fe+	0.3-1	0.00	1.30	0.25	0.45	1.78	0.00	4.90	0.52	1.26	2.44
Cl–	250 - 1000	10.10	18.20	14.82	3.23	0.22	8.00	18.00	13.08	5.64	0.43
HCO_3-	400	0.00	1.40	0.09	0.34	3.78	0.00	4.90	0.52	1.26	2.42
NO_3 -	45	0.00	0.00	0.00	0.00	ND	0.00	1.50	0.25	0.39	1.53
SO_4 -	200 - 400	0.00	21.00	2.97	6.41	2.16	0.00	26.70	3.48	7.29	2.09
F -	1-1.5	0.00	1.40	0.42	0.40	0.96	0.00	1.22	0.34	0.34	1.00

A two-way test

ANNOVA: MS Excel was used to perform the ANNOVA two-way test for all parameters on both open wells and surangam water samples. ANNOVA two-way test results for the open-well and surangam are displayed in (Table 5-6).

Table 5 ANNOVA two-way test -open well water

Parameters	ANOVA- Test	df	P-value	F crit	Parameters	ANOVA- Test	df	P-value	F crit
pH	Between locations	12.00	0.33	2.18	Fe	Between locations	12.00	0.08	2.69
	Between seasons	2.00	0.26	3.40		Between seasons	1.00	0.58	4.75
TDS	Between locations	12.00	0.00	2.69	HCO_3	Between locations	12.00	0.83	2.18
	Between seasons	1.00	0.00	4.75		Between seasons	2.00	0.00	3.40
Turbidity	Between locations	12.00	0.00	2.69	Cl	Between locations	12.00	0.00	2.69
	Between seasons	1.00	0.16	4.75		Between seasons	1.00	0.00	4.75
EC	Between locations	12.00	0.00	2.69	NO_3	Between locations	12.00	0.50	2.69
	Between seasons	1.00	0.00	4.75		Between seasons	1.00	0.04	4.75
Ca^{++}	Between locations	12.00	0.00	2.69	SO_4	Between locations	12.00	0.00	2.69
	Between seasons	1.00	0.00	4.75		Between seasons	1.00	0.12	4.75
Mg^{++}	Between locations	12.00	0.00	2.69	F	Between locations	12.00	0.00	2.69
	Between seasons	1.00	0.00	4.75		Between seasons	1.00	0.00	4.75
Na^+	Between locations	12.00	0.37	2.69	TH	Between locations	12.00	0.00	2.69
	Between seasons	1.00	0.00	4.75		Between seasons	1.00	0.00	4.75
K^+	Between locations	12.00	0.08	2.69					
	Between seasons	1.00	0.00	4.75					

Two factors (quality parameters such as pH, turbidity, iron, and sulphate) for open-well water samples did not show a statistically significant difference between the seasons and locations and for pH, bicarbonate, and nitrate the P value is > 0.05; however, there was a statistically significant difference between the seasons and between the locations ($P < 0.05$) for other parameters. For the Surangam water samples, turbidity, iron, sodium, bicarbonate fluoride, and nitrate did not show a statistically significant difference between the seasons or between the locations ($P > 0.05$) according to a two-factor without replication statistical analysis of the quality parameter bicarbonate [14]. However, for other parameters, there was a statistically significant difference between the seasons and between the locations ($P < 0.05$).

Table 6 ANNOVA two-way test - Suranga water

Parameters	ANOVA- Test	df	P-value	F crit	Parameters	ANOVA- Test	df	P-value	F crit
pH	Between locations	15.00	0.10	2.01	K^+	Between locations	15.00	0.54	2.01
	Between seasons	2.00	0.00	3.32		Between seasons	2.00	0.00	3.32
TDS	Between locations	15.00	0.00	2.01	Fe	Between locations	15.00	0.48	2.01
	Between seasons	2.00	0.00	3.32		Between seasons	2.00	0.00	3.32
Turbidity	Between locations	15.00	0.35	2.01	HCO_3	Between locations	15.00	0.22	2.01
	Between seasons	2.00	0.00	3.32		Between seasons	2.00	0.97	3.32
EC	Between locations	15.00	0.00	2.01	Cl	Between locations	15.00	0.00	2.01
	Between seasons	2.00	0.00	3.32		Between seasons	2.00	0.00	3.32
Ca^{++}	Between locations	15.00	0.02	2.01	NO_3	Between locations	15.00	0.49	2.01
	Between seasons	2.00	0.00	3.32		Between seasons	2.00	0.00	3.32
Mg^{++}	Between locations	15.00	0.00	2.01	F	Between locations	15.00	0.37	2.01
	Between seasons	2.00	0.00	3.32		Between seasons	2.00	0.00	3.32
Na^+	Between locations	15.00	0.44	2.01	TH	Between locations	15.00	0.00	2.01
	Between seasons	2.00	0.00	3.32		Between seasons	2.00	0.00	3.32

Water quality index (WQI)

Water quality index is a single number used to describe the overall suitability of the water at a given place and time, based on a variety of water quality criteria. The most prevalent and easily obtainable kind of index is the WQI. (Table 7-8) shows the calculated WQI values for open-wells and Surangam the classification of drinking water based on the Water quality index (WQI) [15].

Table 7 Water quality index (WQI) - Open-well samples

Locations	WQI		Water quality classification	Locations	WQI		Water quality classification
	PRM	POM			PRM	POM	
OW1	1	1	A	OW13	370	147	E
OW2	58	49	A	OW + SW17	1	14	A
OW3	94	105	E	OW19	33	30	A
OW4	394	340	E	OW + SW20	1	14	A
OW5	356	262	E	OW23	16	14	A
OW6	29	3	A	OW28	8	7	A
OW + SW7	0	3	A	OW29	1	1	A
OW8	11	0	A	OW30	1	1	A

Table 8 Water quality index (WQI) - Surangam water

Locations	WQI		Water quality classification	Locations	WQI		Water quality classification
	PRM	POM			PRM	POM	
SW9	1	2	A	SW22	1	14	A
SW10	0	3	A	SW24	1	14	A
SW11	1	3	A	SW25	1	14	A
SW12	1	2	A	SW26	0	0	A
SW14	1	108	E	SW27	1	7	A
SW15	1	9	A				
SW16	1	16	A				
SW21	53	30	A				

The center portion and southeast region of Padre microwatershed shows the quality of water is suitable for drinking purposes with Water quality index (WQI) ranging from 0 to 58 in the pre-monsoon season and 0 to 49 in the post-monsoon season. Out of all the water quality statuses in open wells, which are unfit for drinking purposes. In Surangam, the WQI values ranging from 0 to 54 in the pre-monsoon and 0 to 39 in the post-monsoon. On the other hand, open well samples namely, OW3, OW4, OW5, and OW13 have Water quality index (WQI) values as 94, 394, 356 and 105, 340, and 262 during pre-monsoon and post-monsoon respectively and are unfit for drinking. Due to fluoride content above the permissible limit, one Surangam S14 near the northeastern portion and during the post-monsoon period the highest Water quality index (WQI) of 108. (Fig 2a-b) shows the spatial distribution of WQI for open wells the during pre- and post-monsoon season and (Fig 2c-d) shows the spatial distribution of Water quality index (WQI) for the Surangam water during pre and post -monsoon season. The map made it evident that the areas with open-wells are not suitable for drinking [16-17].

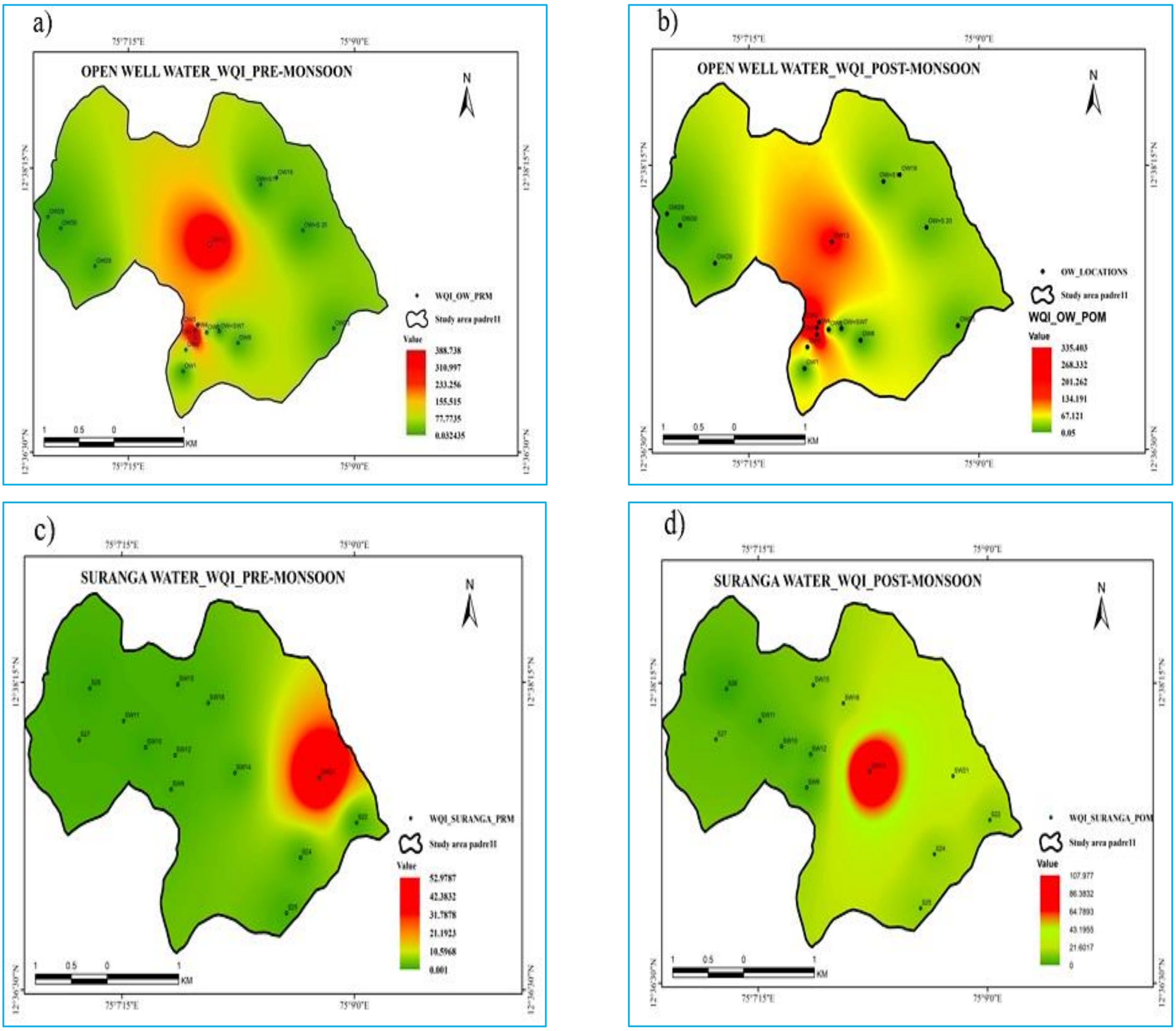

Fig 2a-b WQI of open well; c-d Surangam (PRM and POM)

CONCLUSION

The Water Quality Index (WQI) values accept the suitability of water for drinking purposes. The center portion and southeast region of Padre microwatershed shows the quality of water is suitable for drinking purposes with WQI ranging from 0 to 58 in the pre-monsoon season and 0 to 49 in the post-monsoon season. Only few open wells namely, OW3, OW4, OW5, OW6, OW7 and OW13 at the bottom of the hillocks unfit for the same. Due to fluoride content above the permissible limit, one Surangam S14 near the northeastern portion and during the post-monsoon period the highest WQI of 108. This shows that proper treatment is necessary before it use for drinking purposes. Moreover, these wells should be protected against the contamination caused due to the fertilizers from agricultural lands.

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