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RESEARCH ARTICLE

Chemical Hydrogeological Study of the Kim River Basin, South Gujarat,India: with Special Reference to Impact of Irrigation on Groundwater Regime.

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Abstract

The groundwater quality in the Kim River Basin, south Gujarat was evaluated for its suitability for irrigation use by setting up a network of 43 observation wells. Seasonal sampling of these wells was carried out for two consecutive years and the groundwater samples were analyzed for various physico-chemical parameters. The aquifer characterization was also done in order to understand the seasonal and spatial groundwater quality fluctuations. Analysis revealed that the pH values of all the samples were alkaline in the range of 7.5 to 8.7 with very little variation on seasonal basis. The Electrical Conductivity showed seasonal variation ranging from 340 to 7700 mS/cm which was attributed to combined effects of aquifer type and extensive irrigation practices in the region. Irrigation water quality indices such as Sodium Absorption Ratio, Soluble Sodium Percentage, Kelly's Ratio, Schoeller's Index and Puri Salt Index were applied to the analyzed groundwater samples. The results clearly indicated that the basaltic aquifers in the upstream had good water quality suitable for irrigation in all the seasons. The sedimentary aquifers in the central part of the Basin had slightly moderate water quality owing to solution weathering and thus, not acceptable for irrigation without proper dilution. The lower basin had high potential of groundwater due to presence of alluvial aquifers but the quality of water was unsuitable for irrigation due to high enrichment in various cations and anions.

Introduction:-

Water is a vital resource for the very existence of human life and its quality is of utmost importance as it is directly related to the human health. Agriculture and industrial sectors are sprawling to meet the demands of the growing populations. Agricultural activities worldwide, account for approximately 70% consumption of freshwater resources followed by industrial and domestic segments (FAO, 2015)[4]. Moreover, the dependency on groundwater has significantly increased due to uncertainty of surface water resources in terms of its quality and quantity.

Chemical characterization of groundwater for irrigation use has been attempted by adopting internationally accepted methods such as Sodium Absorption Ratio (SAR), Kelly's Ratio (KR), Soluble Sodium Percentage (SSP), Permeability Index (PI) and Residual Sodium Carbonate (RSC) to define its suitability for irrigation purpose.

Study Area:-

The Kim River constitutes, an independent and relatively smaller watershed basin, falling within the jurisdiction of Bharuch and Surat Districts of south Gujarat, India. Geographically it is bounded between the co-ordinates N - 21^0 19': 21^0 38' and E – 72^0 40': 73^0 27'and sprawling in 1330 km^2 area. The River flows in the south-west direction covering a total length of 107 km and ultimately debouches in the Gulf of Khambhat (Fig.1).The River shares its watershed boundaries with two major fluvial systems of Gujarat, viz., the Narmada River in its north and the Tapi River in its south.

The average annual rainfall of the watershed is 1000 mm^2. The study area constitutes a part of rich agricultural belt of south Gujarat, characterized by a very well-knitted network of canal system. The Pingut and Baldeva are the two medium irrigation schemes in the upper part of the basin; whereas middle and lower part of the basin is benefited by the Ukai-Kakrapar Irrigation canal system. The watershed area is known for growing paddy-sugarcane-cotton-pulses and a variety of cash crops.

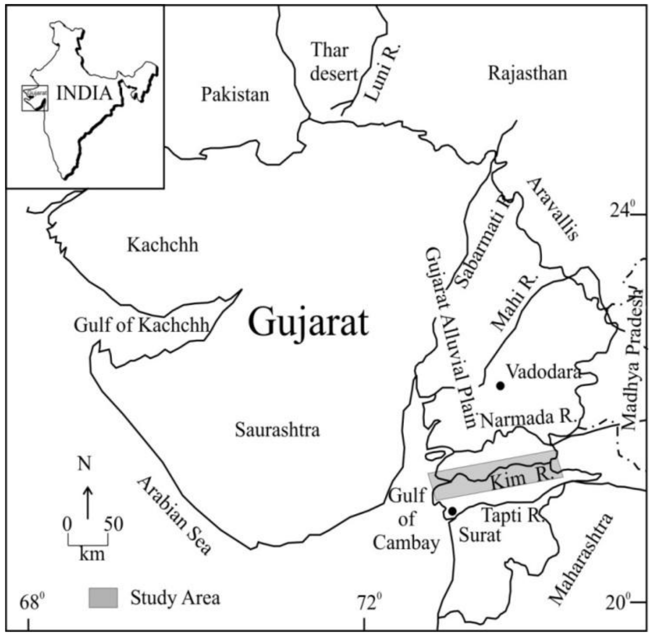

Figure 1: Location of Kim River Basin

Hydrological Characteristics:-

The Kim River Basin is characterized by three distinct hydrogeological units (Fig.2) viz.

i. *Consolidated Sediments:* The basaltic lava flows occupying the upper basin fall within this category. The aquifers are predominantly phreatic type restricted within the weathered and fractured parts of the basalts. Aquifers display high order (up to 10m) of seasonal fluctuations in its water table. Aquifers are characterized by low to moderate yield (120-340 liters per minute)

ii. *Semi-Consolidated Sediments:* The middle part of the basin is occupied by the Tertiary sedimentary sequence comprising conglomerate-sandstone-shale and limestones. Aquifers developed within sandstones are ideal source of water; whereas, limestones being lacking secondary porosity, develop as poor aquifers. These aquifers are also characterized by a marked seasonal fluctuation in the water table and is of moderate yield(250-450 liters per minute)

iii. *Unconsolidated Sediments:* Middle and lower parts of the basin inhibit a thick pile of fluviotile and estuarine sediments of Holocene-Quaternary age. The flood plain deposits in particular area are rich repository of groundwater. The aquifers are multi-layered phreatic to confined in nature. However on approaching towards the coast, aquifers are brackish-saline due to the factors like sediments, inherent salinity, sea water intrusion and water logging.

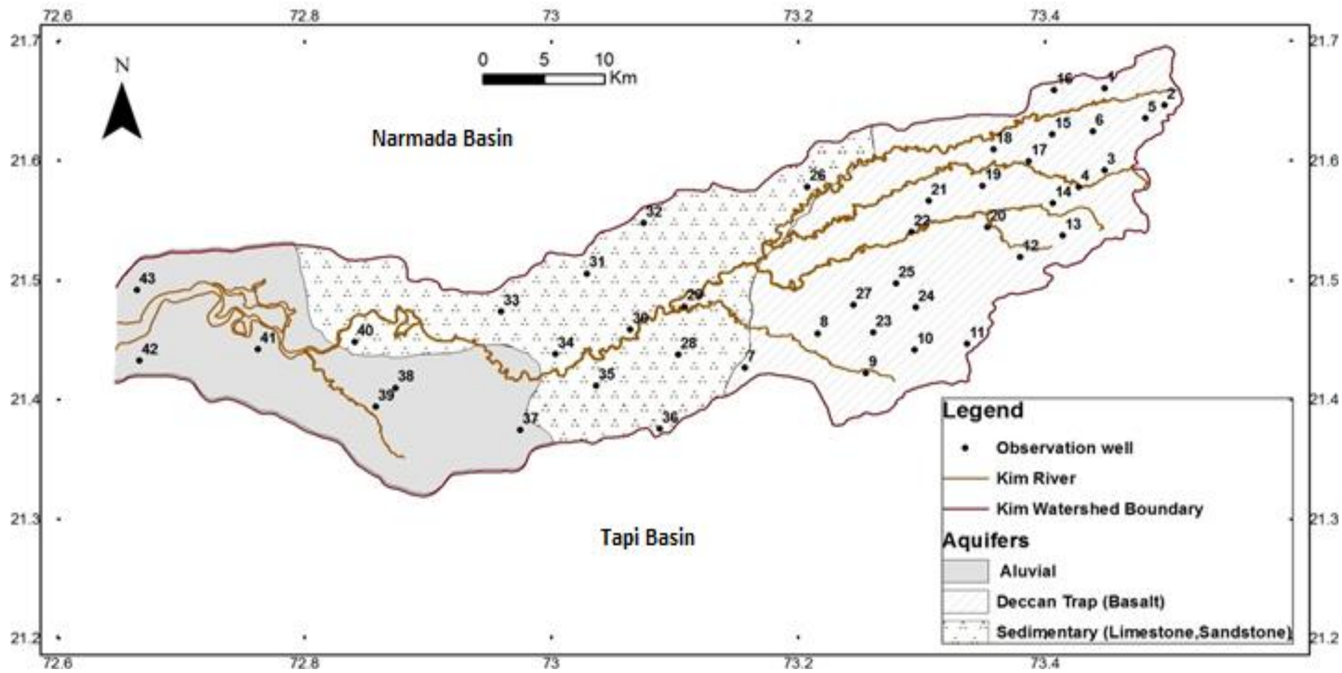

Figure 2: Hydrogeological Map of Kim Watershed

As the canal irrigation in this region is very well developed, the groundwater resources are almost neglected. Thus water intensive cropping pattern and over irrigation has resulted in excessive returned irrigation seepage that has led to slow and steady rise in the water table and overall quality deterioration. This study is an attempt to capsulate the chemical characterization of groundwater based on seasonal changes and spatial variations; and also evaluating its suitability from irrigation point of view by application of appropriate scales and indices.

Methodology:

For monitoring the groundwater on seasonal basis, the study area was divided into equal grids (3km x 3km) and a network of observation wells was set up. In all, 43 groundwater sampling locations were selected which were all dug wells so that the water table can be monitored (Fig. 2).Observation wells located in the upstream of the river system, had partially weathered basalt or amygdaloidal basaltic aquifers which would usually run dry during the summer season. Thus, the number of sampling locations in the upstream is slightly more than those in the rest of the river basin. The sampling was carried out for two consecutive years of 2012 and 2013 on seasonal basis. Pre-monsoon sampling was done in May while the Post-monsoon sampling was carried out in October.

Groundwater samples were collected in clean, sterile, white cans of 1L capacity. Conductivity, pH and temperature were measured in-situ while rests of the parameters were analyzed in the laboratory using Standard Methods for Water Analysis[9]. (Table 1)

Sr. No.	Parameter	Method/Instrument
1.	pH	pH Meter
2.	Electrical Conductivity	EC meter
3.	TDS	Gravimetric Method
4.	Hardness	EDTA Complexometric Titration
5.	Chlorides	Argentometric Titration
6.	Phosphates	Stannous Chloride Colorimetric Method
7.	Sulphates	Barium Chloride Precipitation Method
8.	Carbonates and Bicarbonates	Sulphuric Acid Titration
9.	Sodium and Potassium	Flame Photometer

Table 1: Methods Used for Chemical Analysis

Results and Discussion:-

Study on regional groundwater quality in irrigation use and impact of irrigation on groundwater quality holds a vital significance in understanding the geo-environmental implications.

10 observation wells located in the upstream of the river were dry during the pre-monsoon sampling and so, are not considered for calculation purpose. Table 3(a) and 3(b) reveal the seasonal chemical composition of groundwater in the Kim River Basin.

Olabode et al (2013) studied the hydro chemical evolution of groundwater in the Akure region of Western Nigeria and calculated parameters such as SAR, SSP, PI, KR and chloro alkaline indices to determine its suitability for irrigation purpose[9]. Similarly, Islam and Shamsad (2009) carried out similar suitability studies for waters of Bogra District in Bangladesh[5].Ackahet (2011) assessed the groundwater quality to meet the criteria for drinking and agricultural purposes in farming and sprawling settlement located in East Municipality of Ghana[1].

India is an agricultural country and majority of farming is based on rain-fed irrigation. For round-the-year farming practices and uncertainty in the monsoon season, various irrigation schemes have come up in different parts of the country to provide sufficient waters for irrigation activities. Khan and Abbasi (2013) assessed the groundwater quality in the Ganga-Nim River Sub Basin in the central Ganga Plain[7], while Ramesh and Bhuvana (2012) analyzed the hydro chemical characteristics of groundwater in Periyakulam Taluka of Theni district of Tamil Nadu[10].Agrawal et al (2013) carried out similar studies in area around Raisar District of Bikaner, Rajasthan[2].Nag and Das(2014) carried out a GIS based study of Suri I and II blocks of Birbhum District in West Bengal to evaluate the groundwater quality for irrigation and domestic purposes[8].

pH:-

All the samples of pre- and post-monsoon (Table 3a and b) were found to have alkaline pH in the range of 7.5 to 8.7. Not much variation was seen in the pH values on the seasonal basis. The values were within the permissible limit of (6.5-8.5) of Irrigation Water Quality Standards. (IS:2296).

Well No.	Village	Parameters															
		pH		EC (mS/cm)		TDS		Cl^-		Ca^{+2}		Mg^{+2}		Na^+		K^+	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	Tadphalia	7.3	7.5	681	563	436	360	53	53	59	101	32	24	21	17	T	T
2	Pingut	7.6	7.7	572	340	366	218	71	62	50	97	18	12	16	12	T	T
4	Maujha	7.6	8.2	719	563	460	360	89	53	63	126	22	9	28	23	T	T
7	Dungri	8.2	7.8	1403	1500	898	960	195	178	88	134	46	28	160	104	4	1
8	Chandaniya	7.7	7.6	884	1438	566	920	107	186	55	151	25	47	33	33	T	T
9	Amkhuta	7.9	8.3	747	281	478	180	107	80	59	105	25	12	25	22	T	T
10	Jharni	7.7	7.4	444	1344	284	860	89	71	34	67	16	27	14	13	T	T
13	Nasarpor	8.2	7.7	547	344	350	220	89	36	55	55	32	20	26	27	T	T
15	Chaswad	7.5	8.6	809	1063	518	680	107	107	29	143	62	25	32	28	T	T
23	Wankal	7.2	8.6	1581	2594	1012	1660	391	231	88	210	134	77	41	32	T	T
24	Pataldevi	7.8	7.9	628	781	402	500	53	71	29	76	36	27	44	30	T	T
26	Deshad	7.6	7.6	4534	3781	2902	2420	781	657	88	252	177	75	340	154	T	T
28	Naogama	7.5	7.6	834	1063	534	680	124	124	46	256	45	165	77	70	T	T
29	Simodra	8	8.7	2250	2656	1440	1700	533	533	34	172	82	46	370	163	7	7
30	Limbada	8.5	7.6	7191	6938	4602	4440	1491	1456	176	340	257	90	760	501	63	48
31	Nandav	7.5	8.5	2234	2531	1430	1620	426	355	34	260	101	17	270	134	27	13
32	Dinod	8	8.5	5644	2063	3612	1320	710	302	160	130	195	45	330	98	439	163
33	Kosamba	7.9	7.6	6384	5406	4086	3460	1331	799	361	365	84	28	560	190	9	3
34	Hathoda	8.3	8.2	3691	4438	2362	2840	888	994	46	126	120	149	580	436	219	164
35	Warethi	8	7.6	2231	2219	1428	1420	515	275	17	50	34	30	490	194	T	T
36	Tadkeshwar	7.8	7.5	1072	938	686	600	178	133	63	105	35	36	610	51	3	1
37	Pipodra	8	8.4	1772	2125	1134	1360	355	293	21	50	36	45	420	180	2	1
38	Simalthu	8.3	8.2	1894	1813	1212	1160	497	391	17	29	21	36	460	194	9	6
39	Kachhab	8.6	8.5	3034	3375	1942	2160	817	577	42	46	28	38	650	436	20	25
40	Vadoli	8.3	8.5	7156	6844	4580	4380	2396	1500	122	113	113	184	1300	671	12	8
41	Koba	8.2	8.4	6894	4125	4412	2640	2325	1207	109	118	104	69	1450	626	33	26
42	Karanj	8.4	8.6	5100	2094	3264	1340	994	160	38	67	67	61	740	162	95	69
43	Kantiajal	8.1	-	1522	-	974	-	337	-	25	-	67	-	210	-	82	-
Irrigation Water Quality Standards (IS:2296)		**6.5-8.5**		**2250**		**2100**		**600**		**-**		**-**		**-**		**-**	

(Note: 1. The TDS and all ionic concentrations are in mg/l 2. *T=Trace, Below Detectable Limit 3. Pre= Pre-monsoon Season, Post =Post-monsoon Season)

Table 3a. Seasonal Chemical Composition of Groundwater in 2012

Well No.	Village	Parameters																			
		pH		EC		TDS		Cl^-		Ca^{+2}		Mg^{+2}		Na^+		K^+		CO_3^{-2}		HCO_3^-	
		Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
1	Tadphalia	7.8	7.4	500	603	320	386	89	43	38	57	67	25	21	12	T	T	90	Ab	122	92
3	Pingut	7.8	7.7	492	781	315	500	53	43	25	79	43	20	18	12	T	T	60	Ab	92	61
4	Maujha	7.8	7.7	344	431	220	276	53	28	29	57	60	14	25	10	T	1	Ab	Ab	488	214
7	Dungri	7.9	7.9	1281	1338	820	856	178	142	46	77	93	42	99	102	6	2	120	Ab	427	61
8	Chandaniya	7.9	7.8	937	1588	600	1016	89	213	21	121	77	59	31	34	T	T	Ab	Ab	397	275
9	Amkhuta	7.9	7.8	906	1034	580	662	71	92	21	106	53	38	27	27	T	T	60	Ab	122	31
10	Jharni	7.9	7.3	344	619	220	396	53	36	34	59	26	25	13	9	T	T	Ab	Ab	336	92
13	Nasarpor	8.1	7.6	1063	494	680	316	53	36	55	57	28	21	20	13	1	T	Ab	Ab	305	183
15	Chaswad	8	7.7	1781	1088	1140	696	124	99	50	87	50	39	60	29	T	T	Ab	Ab	336	122
23	Wankal	7.8	8.1	2531	1069	1620	684	373	142	143	45	71	67	30	21	T	T	Ab	Ab	397	275
24	Pataldevi	8	7.9	2906	716	1860	458	71	43	25	45	41	32	31	24	T	T	30	Ab	336	153
26	Deshad	7.8	7.5	2031	425	1300	272	852	36	126	101	162	138	183	38	1	2	Ab	Ab	458	366
28	Naogama	7.9	7.3	1250	1122	800	718	89	128	143	32	118	68	56	75	T	1	Ab	Ab	519	427
29	Simodra	8	7.6	3844	2631	2460	1684	692	575	147	34	66	123	193	181	21	4	60	Ab	305	214
30	Limbada	7.9	7.8	6250	3084	4000	1974	1207	639	235	30	149	162	253	300	45	20	90	Ab	732	641
31	Nandav	7.7	7.9	2813	1788	1800	1144	444	234	176	44	65	80	143	124	24	22	Ab	Ab	824	31
32	Dinod	7.8	8	7625	1866	4880	1194	1118	192	340	102	170	31	178	93	326	141	Ab	Ab	488	397
33	Kosamba	7.6	7.8	3813	2231	2440	1428	692	355	147	143	122	44	168	114	4	3	Ab	Ab	214	92
34	Hathoda	7.8	-	3500	-	2240	-	994	-	113	-	150	-	293	-	191	-	90	-	610	-
35	Warethi	8.1	8.4	2656	2216	1700	1418	337	341	25	18	45	34	233	76	1	1	60	120	427	366
36	Tadkeshwar	7.8	7.8	4719	1153	3020	738	195	163	29	129	104	23	35	54	1	1	Ab	Ab	366	336
37	Pipodra	8.3	8.4	2034	2041	1302	1306	337	284	84	17	39	46	203	189	4	2	90	60	519	366
38	Simalthu	8.1	8.2	1625	2506	1040	1604	426	568	46	34	11	28	223	710	7	8	120	Ab	275	61
39	Kachhab	8.3	8.5	3156	3903	2020	2498	799	873	50	55	54	75	318	420	34	42	60	60	458	427
40	Vadoli	8	8	7500	6272	4800	4014	1953	1527	67	67	239	214	443	565	11	9	30	Ab	427	397
41	Koba	7.6	7.7	3469	7738	2220	4952	799	2123	84	176	34	165	308	505	35	21	30	Ab	1007	854
42	Karanj	8.4	8.5	3031	7541	1940	4826	408	1072	25	27	19	168	253	645	75	123	150	120	519	549
43	Kantiajal	8.2	8.3	1250	4428	800	2834	178	781	21	60	38	100	87	315	77	64	90	60	427	458
Irrigation Water Quality Standards (IS:2296)		**6.5-8.5**		**2250**		**2100**		**600**		**-**		**-**		**-**		**-**		**-**		**-**	

(Note: 1. The TDS and all ionic concentrations are in mg/l 2. *T=Trace, Below Detectable Limit . Pre= Pre-monsoon Season, Post =Post monsoon Season)

Table 3b. Seasonal Chemical Composition of Groundwater in 2013

Electrical Conductivity:-

The Electrical Conductivity (Table 3a & b) shows marked seasonal variation ranging from 340 to 7700 mS/cm. The lower reaches of river basin point to very high EC values indicating high salinity. It was observed that the groundwater samples collected from the wells comprising basaltic aquifers had low EC during the pre-monsoon season while in the post-monsoon season; there has been a significant rise. This change may be ascribed to dissolution of salts due to rock-water interaction and flushing effect. On the contrary, the samples collected from the sedimentary and alluvial aquifers point to lower EC values in post-monsoon seasons because of higher degree of dilution occurred in the groundwater systems in the central and lower parts of the river basin. 54% of samples in the pre-monsoon seasons and 68% samples in the post-monsoon seasons were having the EC within the permissible limit of 2250mS/cm. (IS: 2296)

Well No.	Indices	Sodium Absorption Ratio		Kelly's Ratio		Soluble Sodium Percentage		Schoeller's Index		Puri Salt Index		Permeability Index	
	Village	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
1	Tadphalia	0.5	0.4	0.14	0.11	12	10	0.52	0.54	-133	-312	28	32
3	Pingut	0.5	0.3	0.17	0.09	14	8	0.57	0.63	-102	-367	35	25
4	Maujha	0.7	0.4	0.20	0.13	17	11	0.41	0.38	-97	-363	52	52
7	Dungri	2.7	2.2	0.63	0.55	38	35	-0.07	0.00	-301	-13	48	46
8	Chandaniya	0.8	0.6	0.24	0.13	19	12	0.50	0.74	-29	-497	44	29
9	Amkhuta	0.7	0.6	0.21	0.15	18	13	0.53	0.57	-68	-392	39	20
10	Jharni	0.4	0.3	0.17	0.09	15	8	0.70	0.66	-98	-252	66	30
13	Nasarpor	0.6	0.6	0.19	0.20	16	16	0.49	0.14	-154	-173	53	45
15	Chaswad	1.1	0.6	0.30	0.15	23	13	0.41	0.58	29	-419	53	30
23	Wankal	0.6	0.5	0.11	0.10	10	9	0.86	0.78	-389	-490	27	35
24	Pataldevi	1.1	0.7	0.36	0.22	26	18	0.04	0.25	48	-162	62	44
26	Deshad	3.7	1.8	0.59	0.33	36	25	0.50	-0.02	749	-390	39	59
28	Naogama	1.4	1.3	0.35	0.28	24	21	0.05	0.12	-137	-347	27	56
29	Simodra	5.6	3.0	1.27	0.61	52	38	0.24	0.52	927	336	50	49
30	Limbada	5.8	7.4	0.77	0.88	42	47	0.42	0.35	1458	1044	41	58
31	Nandav	3.8	2.4	0.80	0.51	42	33	0.22	0.25	492	-111	48	43
32	Dinod	3.0	2.0	0.42	0.47	29	32	0.12	-0.19	20	-101	27	56
33	Kosamba	4.7	2.4	0.69	0.43	39	30	0.49	0.57	533	-495	37	39
34	Hathoda	7.2	6.2	1.37	1.01	54	50	0.08	0.18	1730	1504	51	48
35	Warethi	11.1	3.9	3.93	1.27	76	55	-0.25	0.29	1651	488	84	81
36	Tadkeshwar	8.0	1.1	2.27	0.27	47	22	-1.76	0.45	1339	-313	34	44
37	Pipodra	8.7	4.9	2.85	1.50	68	60	-0.37	0.02	1256	732	72	83
38	Simalthu	12.6	17.6	5.32	4.78	82	77	-0.12	-0.34	1503	2040	92	91
39	Kachhab	13.2	10.4	4.17	2.75	76	72	0.06	0.02	2123	1830	79	77
40	Vadoli	13.0	9.1	2.24	1.28	62	56	0.41	0.37	3769	2560	52	59
41	Koba	15.4	9.5	3.19	1.65	74	60	0.21	0.41	3795	2030	85	58
42	Karanj	13.0	7.8	4.10	1.33	80	55	-0.16	-0.47	2255	1729	95	72
43	Kantiajal	3.8	6.4	1.11	1.20	52	55	-0.15	0.31	607	1235	80	66

(* Pre= Premonsoon Season, Post =Post monsoon Season)

Table 4 : Indices for Irrigation Water Quality

Table 4. shows the Water Quality Indices for groundwater samples in the study area. All the above indices were first calculated using various cations and anions for individual seasons and then the average of the obtained indices was taken for pre-monsoon and post -monsoon seasons for graphical and spatial representation.

Sodium Absorption Ratio (SAR):

Sodium Absorption Ratio (SAR) (Richards,1954) indicates the degree to which water tends to enter into cation-exchange reactions in the soil. The sodium or alkali hazard in groundwater is determined by the concentration of cations and is expressed in terms of SAR. If groundwater used for irrigation is high in sodium and low in calcium, the cation-exchange complex may become saturated with sodium.

Thus, SAR value for a given groundwater provides a useful index of the sodium hazard. The SAR is calculated as-

(All the values are in meq/l)

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

The U.S. Salinity Laboratory has given a diagram interrelating the SAR and EC to find out the degree of suitability of ground waters in terms of Salinity and Alkalinity hazards(Richards,1954)[9].

Salinity Hazard Class	EC (mS/cm)	Hazard Class	Percentage of Samples	
			Premonsoon	Post monsoon
C1	<250	Low	0	0
C2	250-750	Medium	14	21
C3	750-2250	High	39	46
C4	>2250	Very High	26	32

Table 5a : Salinity hazard classification on the basis of EC Values (After Richard, 1954)

Sodium Hazard Class	SAR	Hazard Class	Percentage of Samples	
			Premonsoon	Post monsoon
S1	<10	Low	79	89
S2	10-18	Medium	21	11
S3	18-26	High	0	0
S4	>26	Very High	0	0

Table 5b : Sodium Hazard Classification on the Basis of SAR Values

Figure 3, Tables 5a & b represent the degree of salinity and alkalinity hazards in the Kim River Basin. The values reflect the difference of SAR on seasonal basis, which shows that the overall quality of groundwater in post-monsoon season is better than the pre-monsoon period. This may be attributed to dilution effect of rainwater. Almost 79% of groundwater samples in pre-monsoon and 89% samples in post-monsoon seasons have SAR<10 which is suitable for irrigation use. According to the U.S.Salinity Chart, only 14% of groundwater samples in the pre-monsoon and 21% in the post-monsoon season fall in the class C2-S1 indicating 'Good Water'. 36% of pre-monsoon and 34% samples of post- monsoon are categorized as moderate waters belonging to C3-S1 and C3-S2 classes for irrigation, while 50% samples in premonsoon and 29% in the post monsoon fall in the class of bad waters which indicate that the waters are unsuitable for irrigation as they are subjected to salinity and alkalinity hazards.

(After Richards, 1954)

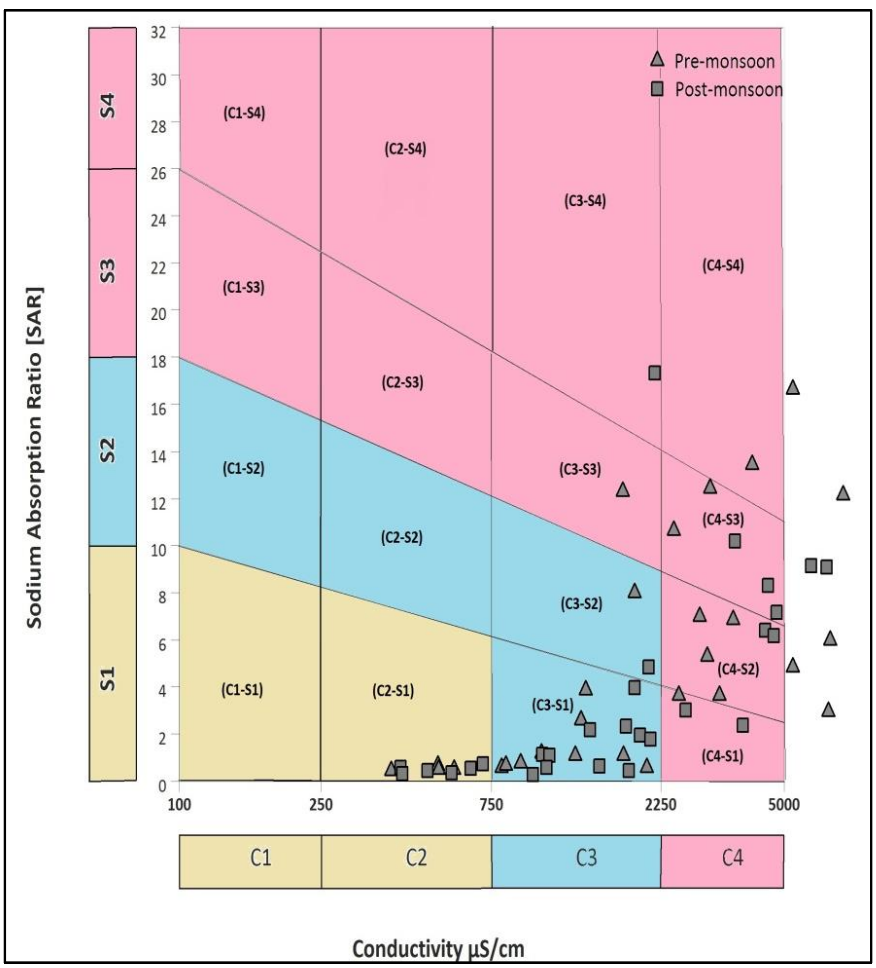

Figure 3:U.S. Salinity Diagram for Classification of Irrigation Water (After Richards, 1954)

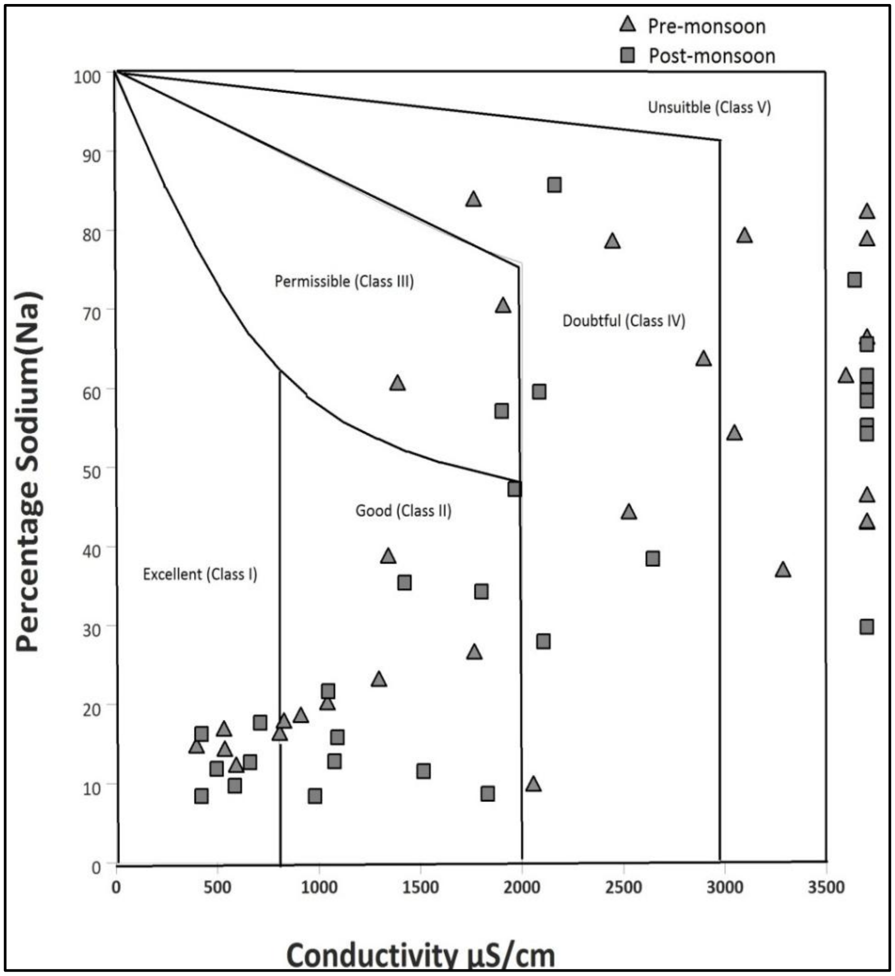

Figure 4: Wilcox Diagram for Sodium Percentage (After Wilcox,1955)

Soluble Sodium Percentage (SSP):

Soluble Sodium Percentage (SSP) determines the ratio of sodium to total cations viz., sodium, calcium and magnesium present in the water. Wilcox (1955) used Percentage Sodium and Electrical Conductance to determine the suitability of water for irrigation purpose.[10] SSP is calculated as-

$$SSP = \frac{Na}{Ca + Mg + Na} \times 100$$

(all the values are in meq/l)

Wilcox classified the suitability of irrigation water by a diagrammatic method in which the percent sodium is plotted against EC values and suggested five distinct categories of water-

Class	Category of Irrigation Water	% Samples	
		Pre monsoon	Post monsoon
I	Excellent	18	21
II	Good	21	32
III	Permissible	7	3
IV	Doubtful	18	14
V	Unsuitable	36	29

Table 6: Wilcox Classification of Irrigation Water based on Sodium Percentage

From, Wilcox diagram (Fig. 4), it can be discerned that, the groundwater during post monsoon season is more suitable for irrigation as compared to pre monsoon season. From Table 6,it can be summarized that 46% of pre monsoon samples and 56% of post monsoon samples are suitable for irrigation purpose and the rest belong to categories of doubtful to unsuitable and can pose a threat to the crops if used for irrigation. Most of the water of the basaltic aquifers located in the upstream of the river fall in the suitable category of water for irrigation, while the quality starts deteriorating it approaches the middle and lower parts of the basin, which may be accounted to the factors of waterlogging and excessive use of agrochemicals.

Kelly's Ratio (KR):

Suitability of water for irrigation purposes is also assessed on the bases of Kelly's Ratio. Kelly et al. (1951) proposed that the potential sodium problems in irrigation water can be evaluated on the basis of following formula-

$$KR = \frac{Na}{Ca + Mg}$$

(all the values are in meq/l)

This ratio reflects the alkali hazards of water. A Kelly's Ratio (KR) >1 indicates an excess level of sodium in waters. Hence, waters with a KR < 1 are suitable for irrigation, while those with a KR >1 are unsuitable for irrigation. The observed KR values show that 61% of pre-monsoon and 68% groundwater samples in the post-monsoon seasons had KR <1.Most of these groundwater samples were from the basaltic and sedimentary aquifers. Remaining ones showing higher KR (>1) belong to the alluvial aquifers in the lower parts of the basin.

Schoeller's Index (SI):

Schoeller (1959) used an index to determine the probable ion exchange reactions occurring in groundwater. The value of the index changes as the groundwater quality varies. The Schoeller's Index(SI) is given by-

$$SI = \frac{Cl - (Na + K)}{Cl}$$

(all the values are in meq/l)

The positive value of the index indicates direct base exchange reaction in the groundwater, i.e. Sodium and Potassium is exchanged with Calcium and Magnesium, while the negative value of the index is indicative of indirect cation-anion exchange. 75% samples in the pre-monsoon and 90% samples in the post-monsoon seasons (Table 4) showed that the SI was positive and thus, direct base exchange reactions were dominant.25% samples in pre-monsoon and only 10% samples in post- monsoon seasons showed negative value of SI indicating indirect cation-anion reactions (Fig.5).Groundwaters in the basaltic aquifers point to direct base exchange reactions in all the seasons, while the chloro-alkali disequilibrium was commonly observed in places having limestone and alluvial aquifers and water-logging is observed as a prominent phenomenon.

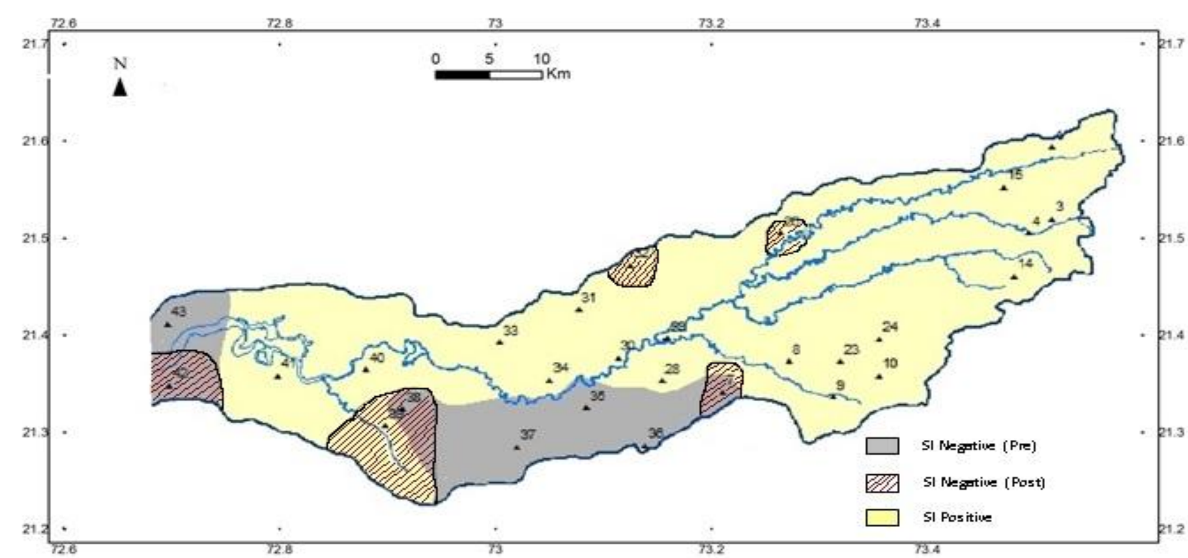

Figure 5: Schoeller's Index for Pre and Post Monsoon Seasons

Puri's Salt Index (PSI):
It is also used for predicting sodium hazard. It is the relation between Na^+, Ca^{2+}, and CaCO3 present in irrigation water. Puri's Salt Index (PSI) is calculated by the following formula-

$$\mathbf{PSI = (Total\ Na) - (total\ Ca\text{-}Ca\ in\ CaCO_3) \times 4.85}$$ ***(All the values are in mg/l)***

PSI is negative for all good water and positive for those unsuitable for irrigation. 46% of pre-monsoon and 61% of post-monsoon groundwater samples indicate negative salt index which classified them under the good water category. The spatial distribution of PSI clearly shows that all the groundwater from the basaltic aquifer along with few samples from sedimentary aquifers had groundwater suitable for irrigation purpose irrespective of the seasonal variation, while all the samples from the alluvial aquifers and few samples from sedimentary aquifers show positive index, indicating that the water is not suitable for irrigation purpose. (Fig.6)

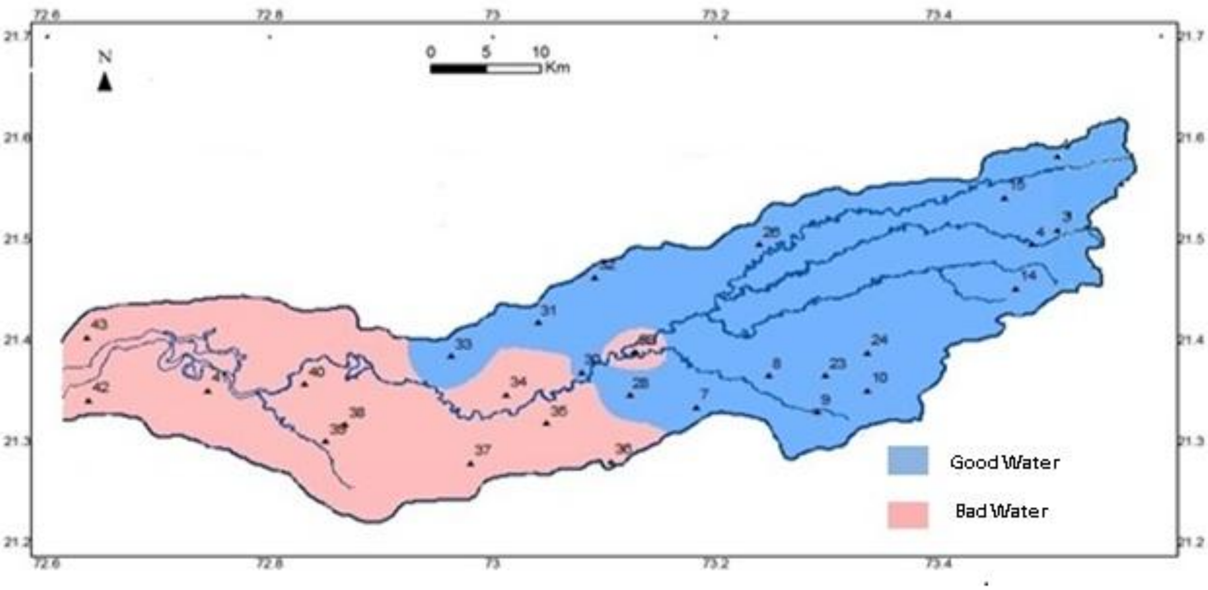

Figure 6: Spatial and Temporal Behaviour of Groundwater in terms of Puri's Salt Index (PSI) in the Kim Basin

Conclusion:
The results of physico-chemical analysis of groundwater samples collected from the various observation wells in the Kim River Basin and the calculated irrigation water quality indices show varied groundwater quality, which may be attributed to presence of different types of aquifers and anthropogenic activities. The consolidated, partially weathered basaltic aquifers in the upstream region have good water quality suitable for irrigation. The semi consolidated sedimentary aquifers of the central part of the Kim River Basin are all year round source of water; however groundwater quality is not acceptable for irrigation due to solution weathering. Groundwater being slightly high in TDS can be used for irrigation after dilution. The unconsolidated alluvial aquifers of the lower basin have high potential of groundwater but the quality of water is not suitable for irrigation as they show high enrichment in various cations and anions. This region being under irrigation canal command area, undergoes extensive agricultural practice throughout the year and so the use of groundwater is restricted. Also the returned irrigation seepage further adds to the groundwater, thus allowing slow and steady rise and also deterioration in the quality due to enrichment in salts. Many regions are facing serious problem of waterlogging which has degraded the soil as well as groundwater quality in the lower reaches of the Kim River Basin.

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