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WATER QUALITY INDEX ASSESSMENT OF GROUND WATER IN JAKKUR SUB WATERSHED OF BANGALORE, KARNATAKA, INDIA

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ABSTRACT

The water quality index (WQI) is a single number that expresses the quality of water by integrating the water quality variables. The purpose is to provide a simple and concise method for expressing the water quality for different usage. The present work deals with the monitoring of variation of seasonal ground water quality index of ground water for Jakkur sub watershed in Bangalore, Karnataka state of India. For calculating the WQI the following 12 physic-chemical parameters such as pH, Electric Conductivity, Total Dissolved Solids, Total Alkalinity, Chlorides, Total Hardness, Dissolved Oxygen, Fluoride, Calcium, Magnesium, Sulphate and Nitrate have been considered. The water quality index value of ground water was 84.46 in rainy season, 77.14 in winter season and 91.22 in summer season. In the present investigation the quality of water was found to be good in and around Jakkur sub watershed.

KEYWORDS: Ground Water, Physico-Chemical Parameters, Water Quality Index, Water Quality Standards

INTRODUCTION

The fresh water is of vital concern for mankind since it is directly linked to human welfare. Ground water is an important natural source of water supply all over the world. Its use in irrigation, industrial and domestic usage continues to increase where perennial surface water source are absent. The modern civilization, over exploitation, rapid industrialization and increased population has lead to fast degradation of our environment. The quality of ground water may depend on geology of particular area and also vary with depth of water table and seasonal changes and is governed by the extent and composition of the dissolved salts depending upon source of the salt and soil-surface environment.

Water quality index provides a single number that expresses overall water quality at a certain location and time, based on several water quality parameters. The objective of water quality index is to turn complex water quality data into information that is understandable and usable for common man. A single number is not enough to describe the water quality: there are many other water quality parameters that are not included in the index. However, a water quality index based on some very important parameters can provide a simple indicator of water quality. In general, water quality indices incorporate data from multiple water quality parameters into a mathematical equation that rates the health of a waterbody with number (Yogendra et al., 2007).

OBJECTIVE OF PRESENT WORK

The objective of the present research is to provide information on the physico-chemical characteristics of ground water in order to discuss it's suitability for human consumption based on computed water quality index values.

PARAMETERS OF WATER QUALITY ANALYSED

For the assessment of water pollution status of the groundwater, the following water quality parameters were analyzed: (1) pH, (2) Electric Conductivity, (3) Total Dissolved Solids, (4) Total Alkalinity, (5) Chlorides, (6) Total

Hardness, (7) Dissolved Oxygen, (8) Fluoride, (9) Calcium, (10) Magnesium, (11) Sulphate and (12) Nitrate.

STUDY AREA

For the present study, Jakkur sub watershed of Bangalore city was selected. Jakkur sub watershed is located at latitude 13° 04'N to 13° 06'N and longitude between 77°35'E to 77° 6'E and is in the North-East corner of Bangalore city and eastern side of NH-4 covers an area of 18.95 sq.km, the same is seen in SOI topo sheet No. 57G/12.

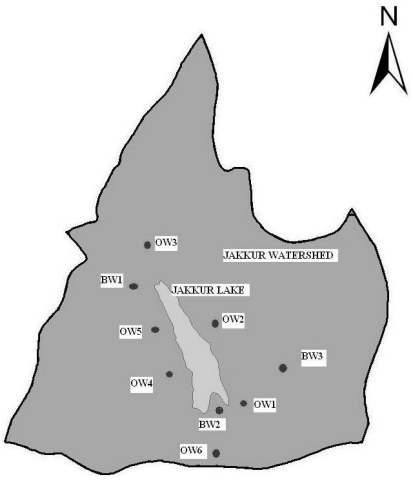

Figure 1: Groundwater Sampling Locations

MATERIALS AND METHODS

The water samples from nine open wells and three bore wells were collected of an interval of 30 days and analysed for 12 physico-chemical parameters by following the established procedures. The parameters pH, electrical conductivity and dissolved oxygen were monitored at the sampling site and other parameters were analysed in the laboratory as per the standard procedure of APHA (1995)

The WQI has been calculated by using the standards of drinking water quality recommended by the World Health Organisation (WHO), Bureau of Indian Standards (BIS) and Indian Council for Medical Research (ICMR). The calculation of WQI was made using a weighted arithmetic index method given below (Brown et al., 1972) in the following steps.

Calculation of Sub Index of Quality Rating (Q_n)

Let there be *n* water quality parameters where the quality rating or sub index (q_n) corresponding to the n^{th} parameter is a number reflecting the relative value of this parameter in the polluted water with respect to its standard permissible value. The value of q_n is calculated using the following expression

$$q_n = 100[(V_n - V_{io})/(S_n - V_{io})] \quad (1)$$

Where,

q_n = quality rating for the n^{th} water quality parameter.

V_n = observed value of the n^{th} parameter.

S_n = standard permissible value of n^{th} parameter.

V_{io} = ideal value of n^{th} parameter in pure water.

All the ideal values (V_{io}) are taken as zero for drinking water except for pH=7.0, Dissolved Oxygen = 14.6 mg/L, and Fluoride = 1 mg/L.

Calculation of Quality Rating for pH

For pH the ideal value is 7.0 (for natural water) and a permissible value is 8.5 (for polluted water). Therefore, the quality rating for pH is calculated from the following relation:

$q_{pH} = 100[(V_{pH}-7.0)/(8.5-7.0)]$

Where,

V_{pH} = observed value of pH during the study period.

Calculation of Quality Rating for Dissolved Oxygen

The ideal value (V_{io}) for dissolved oxygen is 14.6 mg/L and standard permitted value for drinking water is 5mg/L. Therefore, quality rating is calculated from following relation:

$q_{DO} = 100[(V_{DO} - 14.6)/(5 - 14.6)]$

Where,

V_{DO} = observed value of dissolved oxygen

Calculation of Quality Rating for Fluoride

The ideal value (V_{io}) for fluoride is 1 mg/L and standard permitted value for drinking water is 1.5 mg/L. Therefore, quality rating is calculated from following relation:

$Q_F = 100[(V_F - 1)/(1.5 - 1)]$

where,

V_F = observed value of fluoride.

Calculation of Unit Weight (W_n)

Calculation of unit weight (W_n) for various water quality parameters are inversely proportional to the recommended standards for the corresponding parameters.

$Wn = K/S_n$

Where,

W_n = unit weight of n^{th} parameters

S_n = standard value for n^{th} parameters

K = constant for proportionality and is given as (Kalavathy et al., 2011):

$K=1/[1/V_{S1}+1/V_{S2}+\ldots\ldots+1/V_{sn}]$

Calculation of WQI

WQI is calculated from the following equation

$$WQI = \sum_{i=1}^{n} q_n W_n / \sum_{i=1}^{n} W_n$$

Table 1 shows the classification of water quality status based on Water Quality index (Ramakrishnaiah et al. 2009, Bhaven et al. 2011 and Srinivasa Kushtagi et. al. 2012,).

Table 1: Water Quality Classification Based on WQI Value

Class	WQI value	Water Quality Status
I	<50	Excellent
II	50-100	Good Water
III	100-200	Poor water
IV	200-300	Very poor water
V	>300	Water unsuitable for drinking

Table 2: Drinking Water Standards, Recommending Agencies and Unit Weights

Sl.No	Parameters	Standard Permissible Value (Sn)	Recommended Agency	1/Sn	Unit Weight
1	PH	8.5	ICMR/BIS	0.118	0.083
2	EC (µ-s/cm)	300	ICMR	0.003	0.002
3	TDS (mg/L)	500	ICMR/BIS	0.002	0.001
4	Total Alkalinity (mg/L)	120	ICMR	0.008	0.006
5	Chlorides (mg/L)	250	ICMR	0.004	0.003
6	Total Hardness (mg/L)	300	ICMR/BIS	0.003	0.002
7	DO (mg/L)	5	ICMR/BIS	0.2	0.141
8	Fluride (mg/L)	1.5	BIS	0.667	0.471
9	Ca (mg/L)	75	ICMR/BIS	0.013	0.009
10	Mg (mg/L)	30	ICMR/BIS	0.033	0.024
11	Sulphate (mg/L)	150	ICMR/BIS	0.007	0.005
12	Nitrate (mg/L)	45	ICMR/BIS	0.022	0.016

Table 3: Seasonal Variations of the Physico-Chemical Parameters

Para-meters	Seasons	Sampling Stations									Min.	Max.	Aver.
		OW1	OW2	OW3	OW4	OW5	OW6	BW1	BW2	BW3			
pH	Rainy	7.2	7.2	5.3	7.1	7.1	7.4	6.7	6.7	7	5.3	7.4	6.88
	Winter	7.3	7.1	6.9	6.9	6.9	7.3	6.6	7.1	6.6	6.6	7.3	6.99
	Summer	7.3	7.3	7.2	6.9	7.1	7.5	7.4	6.5	6.8	6.5	7.5	7.11
EC µ-s/cm	Rainy	1112	779.6	631.3	1083	874.2	929.4	920.1	1478	936.2	631	1478	971.6
	Winter	1064	880.8	843.4	1055	877.6	912.2	857.2	1274	856.8	843	1274	957.8
	Summer	1024	864.9	671.2	1055	825.2	891.5	788.2	1374	859.4	671	1374	928.1
TDS mg/L	Rainy	518.1	359	239.3	460	380.7	414.7	360.2	660.9	461.2	239	660.9	428.2
	Winter	429	378.7	316.2	486.2	377.4	405.9	364.7	469.3	410.6	316	486.2	404.2
	Summer	513.2	421.1	319.3	529.6	409	442.9	381.6	688.9	455.2	319	688.9	462.3
TA mg/L	Rainy	206.3	96.6	153.8	114.4	176.4	163.5	191.4	162.9	171.3	96.6	206.3	159.6
	Winter	234	105	190	125	202	157	192	179	191	105	234	175
	Summer	164	91	165.3	93	179	132	165	149	160	91	179	144.3
Cl mg/L	Rainy	234.5	205	100	289.2	181.2	192.5	180	360	181.2	100	360	213.7
	Winter	206.5	237	146	279.5	161.5	179.5	160.5	275.5	132.5	133	279.5	197.6
	Summer	244	231.5	112.7	294.5	162	200.5	156	338.5	161	113	338.5	211.2
TH mg/L	Rainy	285.9	135.8	197.6	164.9	242.7	311.2	323.1	507.5	315.6	136	507.5	276
	Winter	274.7	155.7	242.8	189.1	252.1	303.9	296.2	386.3	259.8	156	386.3	262.3
	Summer	250.4	159	174	177	234.6	302.5	259.5	451.5	267.3	159	451.5	252.9

Table 3: Contd.,

DO mg/L	Rainy	6.8	6.5	5.1	6.3	6.7	6.4	6.2	5.7	6.6	5.1	6.8	6.25
	Winter	5.5	6	5.9	5.5	5.9	6.3	6.1	6	6.2	5.5	6.3	5.92
	Summer	6.2	6.3	6.2	6.2	6.6	5.9	5.8	5.4	6.8	5.4	6.8	6.16
F mg/L	Rainy	0.7	0.5	0.4	0.4	0.4	0.4	0.6	0.4	0.8	0.4	0.8	0.52
	Winter	0.7	0.6	0.7	0.5	0.4	0.5	0.6	0.4	0.8	0.4	0.8	0.58
	Summer	0.7	0.5	0.6	0.3	0.3	0.4	0.4	0.3	0.8	0.3	0.8	0.47
Ca mg/L	Rainy	57.4	30.7	39.9	51.6	51.1	54.2	65.4	89.9	54.3	30.7	89.9	54.93
	Winter	44.4	22.5	43.1	36.9	37.8	39	46.4	71.6	35.4	22.5	71.6	41.9
	Summer	29.2	33.6	28.8	28	34.8	34.4	24.8	41.6	26.4	24.8	41.6	31.29
Mg mg/L	Rainy	34.7	14.4	23.9	8.8	28.1	42.9	38.9	69	43.9	8.8	69	33.84
	Winter	39.9	24.3	32.9	23.7	38.4	50.4	43.9	50.6	41.8	23.7	50.6	38.44
	Summer	43.3	18.3	24.9	26.1	36	52.8	48.2	84.8	49.1	18.3	84.8	42.61
SO_4 mg/L	Rainy	10.9	5.5	23	17.6	10.8	14.5	12.2	39.2	26.2	5.5	39.2	17.76
	Winter	13.6	7.5	15.5	6.6	12.2	20.4	13.2	50.8	28	6.6	50.8	18.64
	Summer	11	5.5	8.8	5.5	9	19.7	10.7	55.3	26.7	5.5	55.3	16.92
NO_3 mg/L	Rainy	8.2	7.9	11.9	18.1	18.7	18.6	4.5	17.3	11.3	4.5	18.7	12.94
	Winter	8.9	10.4	13.3	12.4	19.9	15.5	7.5	12.6	10.6	7.5	19.9	12.32
	Summer	14.3	10.5	14.7	18.6	23.1	21	6.1	15.9	11.6	6.1	23.1	15.08

Table 4: Calculation of Water Quality Index in Rainy Season

Rainy Season							
Sl.No.	**Parameters**	**Standard Value (Sn)**	**1/Sn**	**Unit Weight (Wn)**	**Observed Values**	**Quality Rating (qn)**	**Weighted (Wnqn)**
1	PH	8.5	0.118	0.083	6.88	-8	0.665
2	EC	300	0.003	0.002	971.56	323.853	0.763
3	TDS	500	0.002	0.001	428.21	85.642	0.121
4	Total Alkalinity	120	0.008	0.006	159.6	133	0.784
5	Chlorides	250	0.004	0.003	213.73	85.492	0.242
6	Total Hardness	300	0.003	0.002	276.03	92.01	0.217
7	DO	5	0.2	0.141	6.25	86.979	12.299
8	Fluride	1.5	0.667	0.471	0.52	-96	45.248
9	Ca	75	0.013	0.009	54.93	73.24	0.69
10	Mg	30	0.033	0.024	33.84	112.8	2.658
11	Sulphate	150	0.007	0.005	17.76	11.84	0.056
12	Nitrate	45	0.022	0.016	12.94	28.756	0.452
			1.08	**∑Wn=0.76**			**∑Wnqn=64.2**
Water Quality Index =84.46							

Table 5: Calculation of Water Quality Index in Winter Season

Winter Season							
Sl.No.	**Parameters**	**Standard Value (Sn)**	**1/Sn**	**Unit Weight (Wn)**	**Observed Values**	**Quality Rating (qn)**	**Weighted (Wnqn)**
1	PH	8.5	0.118	0.083	6.99	-0.667	0.055
2	EC	300	0.003	0.002	957.81	319.27	0.752
3	TDS	500	0.002	0.001	404.23	80.846	0.114
4	Total Alkalinity	120	0.008	0.006	175	145.833	0.859
5	Chlorides	250	0.004	0.003	197.61	79.044	0.224
6	Total Hardness	300	0.003	0.002	262.27	87.423	0.206
7	DO	5	0.2	0.141	5.92	90.417	12.785
8	Fluride	1.5	0.667	0.471	0.58	-84	39.592
9	Ca	75	0.013	0.009	41.9	55.867	0.527

Table 5:Contd.,							
10	Mg	30	0.033	0.024	38.44	128.133	3.02
11	Sulphate	150	0.007	0.005	18.64	12.427	0.059
12	Nitrate	45	0.022	0.016	12.32	27.378	0.43
			1.081	**∑Wn=0.76**			**∑Wnqn=58.62**
Water Quality Index =77.14							

Table 6: Calculation of Water Quality Index in Summer Season

Summer Season							
Sl.No.	**Parameters**	**Standard Value (Sn)**	**1/Sn**	**Unit Weight (Wn)**	**Observed Values**	**Quality Rating (qn)**	**Weighted (Wnqn)**
1	PH	8.5	0.118	0.083	7.11	7.333	0.61
2	EC	300	0.003	0.002	928.11	309.37	0.729
3	TDS	500	0.002	0.001	462.3	92.46	0.131
4	Total Alkalinity	120	0.008	0.006	144.26	120.217	0.708
5	Chlorides	250	0.004	0.003	211.18	84.472	0.239
6	Total Hardness	300	0.003	0.002	252.87	84.29	0.199
7	DO	5	0.2	0.141	6.16	87.917	12.431
8	Fluride	1.5	0.667	0.471	0.47	-106	49.961
9	Ca	75	0.013	0.009	31.29	41.72	0.393
10	Mg	30	0.033	0.024	42.61	142.033	3.347
11	Sulphate	150	0.007	0.005	16.92	11.28	0.053
12	Nitrate	45	0.022	0.016	15.08	33.511	0.526
			1.081	**∑Wn=0.76**			**∑Wnqn=69.33**
Water Quality Index =91.22							

Table 7: GWQI at Individual Sampling Stations

Seasons	Sampling Stations								
	OW1	**OW2**	**OW3**	**OW4**	**OW5**	**OW6**	**BW1**	**BW2**	**BW3**
Rainy	60.97	78.12	95.69	97.77	97.4	95.48	70.88	103.12	47.1
Winter	59.85	67.09	61.61	87.19	94.94	87.13	77.48	101.18	50.79
Summer	65.45	88.7	70.21	109.46	110.49	105.35	96.03	117.77	50.56

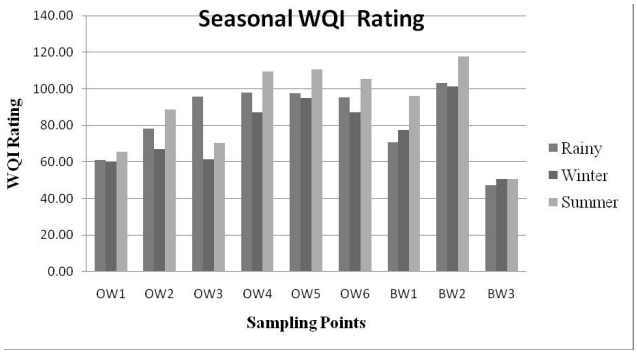

Figure 2: Water Quality Index for Different Seasons

RESULTS AND DISCUSSIONS

The analytical results obtained for different study parameters such as pH, EC, TDS, Alkalinity, Chlorides, Hardness, Dissolved Oxygen, Fluoride, Calcium, Magnesium, Sulphate and Nitrate from different sampling locations in

different seasons of the year 2011-2012 are summerised in Table 3. Permissible limits and recommended agenesis are described in Table 2. The results obtained season wise are discussed below.

Rainy Season

The physical and chemical water quality parameters analyzed at 9 different locations and their minimum, maximum and mean values are reported in Table 3. The pH value of the ground water samples in the rainy season vary from 5.3 to 7.4 at all sampling locations with an average of 6.88, while the ranges of EC and TDS were 631.3 µ-s/cm to 1478 µ-s/cm and 239.3 mg/L to 660.9 mg/L at all sampling locations with mean values 971.56 µ-s/cm and 428.21 mg/L respectively. The mean value of EC is above the permissible limit and the mean value of TDS is below the permissible limit. The total alkalinity values at all sampling locations vary from 96.6 mg/L to 206.3 mg/L at all sampling locations with an average value of 159.6 mg/L. Chloride and hardness values at all sampling point locations vary from 100 mg/L to 360 mg/L and 135.8 mg/L to 507.5 mg/L with mean values of 159.6 mg/L and 276.03 mg/L. The mean values of total chloride and hardness are observed below the permissible limits. The dissolved oxygen value of ground water vary from 5.1 mg/L to 6.8 mg/L at all sampling locations with an average value of 6.25 mg/L. Fluoride, Sulphat and Nitrate concentration varied between the range of 0.4 mg/L to 0.8 mg/L, 5.5 mg/L to 39.2 mg/L and 4.5 mg/L to 18.7 mg/L at all sampling locations with its mean observed value of 0.52 mg/L, 17.76 mg/L and 12.94 mg/L respectively. The average values of all these parameters are found below the drinking standards. The range of calcium and magnesium were 30.7 mg/L to 89.9 mg/L and 8.8 mg/L to 69.0 mg/L at all sampling locations with mean values of 54.93 mg/L and 33.84 mg/L respectively. The concentration of calcium is found below the permissible limit, whereas the mean concentration of magnesium is found to be above the permissible limit.

Winter Season

The pH value of the ground water samples in winter season vary from 6.6 to 7.3 at all sampling locations with an average of 6.99, while the ranges of EC and TDS were 843.4 µ-s/cm to 1273.8 µ-s/cm and 316.2 mg/L to 486.2 mg/L at all sampling locations with mean values 957.81 µ-s/cm and 404.23 mg/L respectively. The mean value of EC is above the permissible limit and the mean value of TDS is below the permissible limit. The total alkalinity values at all sampling locations vary from 105 mg/L to 234 mg/L at all sampling locations with an average value of 175 mg/L. Chloride and hardness values at all sampling point locations vary from 132.5 mg/L to 279.5 mg/L and 155.7 mg/L to 386.3 mg/L with mean values of 197.61 mg/L and 262.27 mg/L. The mean values of total chloride and hardness are observed below the permissible limits. The dissolved oxygen value of ground water vary from 5.5 mg/L to 6.3 mg/L at all sampling locations with an average value of 5.92 mg/L. Fluoride, Sulphat and Nitrate concentration varied between the range of 0.4 mg/L to 0.8 mg/L, 6.6 mg/L to 50.8 mg/L and 7.5 mg/L to 19.9 mg/L at all sampling locations with its mean observed value of 0.58 mg/L, 18.64 mg/L and 12.32 mg/L respectively. The average values of all these parameters are found below the drinking standards. The range of calcium and magnesium were 22.5 mg/L to 71.6 mg/L and 23.7 mg/L to 50.6 mg/L at all sampling locations with mean values of 41.9 mg/L and 38.44 mg/L respectively. The concentration of calcium is found below the permissible limit, whereas the mean concentration of magnesium is found to be above the permissible limit.

Summer Season

The pH value of the ground water samples in summer season vary from 6.5 to 7.5 at all sampling locations with an average of 7.11, while the ranges of EC and TDS were 671.2 µ-s/cm to 1374 µ-s/cm and 319.3 mg/L to 688.9 mg/L at all sampling locations with mean values 928.11 µ-s/cm and 462.3 mg/L respectively. The mean value of EC is above the permissible limit and the mean value of TDS is below the permissible limit. The total alkalinity values at all sampling

locations vary from 91 mg/L to 179 mg/L at all sampling locations with an average value of 144.26 mg/L. Chloride and hardness values at all sampling point locations vary from 112.7 mg/L to 338.5 mg/L and 159 mg/L to 451.5 mg/L with mean values of 211.18 mg/L and 252.87 mg/L. The mean values of total chloride and hardness are observed below the permissible limits. The dissolved oxygen value of ground water vary from 5.4 mg/L to 6.8 mg/L at all sampling locations with an average value of 6.16 mg/L. Fluoride, Sulphate and Nitrate concentration varied between the range of 0.3 mg/L to 0.8 mg/L, 5.5 mg/L to 55.3 mg/L and 6.1 mg/L to 23.1 mg/L at all sampling locations with its mean observed value of 0.47 mg/L, 16.92 mg/L and 15.08 mg/L respectively. The average values of all these parameters are found below the drinking standards. The range of calcium and magnesium were 24.8 mg/L to 41.6 mg/L and 18.3 mg/L to 84.8 mg/L at all sampling locations with mean values of 31.29 mg/L and 42.61 mg/L respectively. The concentration of calcium is found below the permissible limit, whereas the mean concentration of magnesium is found to be above the permissible limit.

Groundwater Quality Assessment

Water quality index computed for the study area in the rainy, winter and summer season are presented in Table 4, 5 and 6 respectively. The computed WQI for rainy season indicate that the overall WQI was 84.46 as compared to winter season 77.14 and summer season 91.22 respectively. The high values of WQI have been found in summer season and lower value in winter season. In all the seasons the ground water quality is found good since the WQI value varying from 77.14 to 91.22. The high value of WQI in summer season is because of high concentration of TDS, magnesium and nitrates in ground water. The physcio-chemical parameter analytical results were also used for calculating WQI for different sampling locations OW1, OW2, OW3, OW4, OW5, OW6, BW1, BW2 and BW3 in rainy, winter and summer seasons. The season wise WQI for all these locations are shown in Table 7 and in Figure 2. Water quality of OW4, OW5 and OW6 tends to poor quality during summer season. But the water quality of BW2 is found to be poor in all the seasons

CONCLUSIONS

At the outset, the overall WQI (Rainy season – 84.46, winter – 77.14 and in Summer-91.22) values computed in all the seasons falls under class II of Table 1, indicates that the water quality is good and suitable for drinking and other domestic purposes. Further, the seasonal values of WQI indicate that in summer season ground water is more affected than during rainy and winter season. But WQI computed for individual sampling sources indicates that in summer season the score is above 100 and falls in class III of poor water quality in the case of some sampling stations. The seasonal variations of index values are due to variation in physicochemical characteristics of ground water.

Application of water quality index (WQI) in this study has been found useful in assessing the overall quality of water. This method appears to be more systematic and gives comparative evaluation of the water quality in different seasons of the year. It is also helpful for public to understand the quality of water as well as being a useful tool in many ways in the field of water quality management.

REFERENCES

1. APHA (1995). Standard Methods (18 Ed.) for the examination of water and waste water, APHA, AWWA, WPCE, Washington DC.
2. Bhaven N. Tandel, JEM Macwan and Chirag K. Soni (2011). *Assessment of Water Quality Index of small lake in south Gujarath region, India*, Proceedings of ISEM-2011, Thailand.
3. BIS 10500, (1991*), Specifications for drinking water*, Indian Standard Institutions (Bureau of Indian Standards), New Delhi.

4. Brown R.M, N.J. Mccleiland, R.A. Deiniger, M.F.A. Oconnor (1972). *Water quality index – crossing the physical barier*, Proc. Int. Conf. on water pollution research, Jerusalem, 6, 787-797.
5. ICMR Manual of standards of quality for drinking water supplies (1975). ICMR, New Delhi.
6. Kalavathy S., T. Rakesh Sharma and P. Sureshkumar (2011), *Water uality Index River Cauvery in Tiruchirappalli district, Tamilnadu*, Arch. Environ. Sci., 5, 55-61.
7. Ramakrishnaiah C.R, C. Sadashivaiah and G. Ranganna (2009). *Assessment of Water Quality Index for theGroundwater in Tumkur Taluk, Karnataka State, India*; E-Journal of Chemistry, 6(2), 523-530.
8. Srinivasa Kushtagi and Padaki Srinivas (2012*). Studies on chemistry and Water Quality Index of ground water in Chincholi Taluk, Gulbarga district, Karnataka India*, International Journal of Environmental Science, 2, 1154-1160.
9. WHO (1992). *International Standards for Drinking Water*. World Health Organization, Geneva, Switzerland
10. Yogendra K. and E.T. Puttaiah (2008). *Determination of water quality index and Suitability of an Urban Waterbody, Shimoga Town, Karnataka*, Proceedings of 12th world Lake Conference 342-346.