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Application of Water Quality Index Method to Assess Groundwater Quality in Mysore City, Karnataka, India

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ABSTRACT: Groundwater is a natural resource for drinking water. Assessment of ground water quality status in Mysore city by using water quality index (WQI) method was carried out. From the sampling locations spread throughout city, 53 groundwater samples were collected both in pre- and post-monsoon seasons. WQI has been determined by subjecting the samples to comprehensive physicochemical analysis. For calculating the WQI, the following 13 parameters have been considered: pH, EC, TH, TDS, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, CO_3^{2-}, HCO_3^{-}, SO_4^{2-}, Cl^{-} and NO_3^{-}. The WQI for the groundwater samples ranges from 42.61 to 109.51 and from 39.82 to 166.19 for PRM and POM seasons respectively. The results of some of the water samples show values over the permissible limits of WHO and BIS standards for drinking waters for parameters such as calcium and magnesium cations, nitrate and sulphate anions, and also in the global parameters: salinity and TDS. The elevated value of WQI has been found to be mainly from the higher values of nitrate and hardness in the groundwater. The analysis reveals that the groundwater of the area needs some degree of treatment before consumption.

KEYWORDS: Water Quality Index, Groundwater quality assessment, Groundwater, Mysore city, Nitrates in water.

I. INTRODUCTION

In addition to population growth, water demand in urban areas is steadily increasing in India, as the cities are attracting more people from the rural areas who come to improve their livelihoods. In the absence of adequate surface water resources, the next most important fresh water source is groundwater. Water authorities may meet the water demand of the general public by supplying water from the surface water and/or groundwater resources. Conjunctive use of surface water and groundwater resources for urban water supply is the current practice in most of the urban areas [1]. Water supplied to the general public warrants water quality protection. Water quality monitoring and assessment are the foundation of water quality management; thus, there has been an increase demand for monitoring water quality of many rivers and ground water by regular measurements of various water quality variables [2] & [3].

Tourism is a major industry in Mysore. The city attracted about 3.15 million tourists in 2010 [4]. In recent years, Mysore city is witnessing a tremendous growth in population owing to urbanization. However, due to inadequate supply of surface water, the residents of Mysore city have sank bore wells on their premises for drinking and domestic purposes. Further, urbanization has given rise to an increased discharge of domestic sewage and solid waste dumping sites. Poor maintenance of sewer pipes, indiscriminate littering of solid waste, possible leakage of septic tanks from the dwellings in unauthorized areas and urban storm water runoff may cause the pollution of groundwater. Under such circumstances, large populations are at risk of exposure to water borne diseases. Hence, physico-chemical analysis of groundwater has become important to assess the quality of groundwater for domestic needs. The general objective of this study is to characterize the quality of groundwater of Mysore city which is experiencing dramatic expansion and to determine the pollutant concentration and its effect on the quality of groundwater. The main objective of this paper is to assess the quality of water of the urban aquifer by comparing the determined levels with the WHO and BIS drinking water standards and to calculate the water quality index (WQI) based on the data collected from 53 groundwater sampling locations throughout the city.

A.Study Area

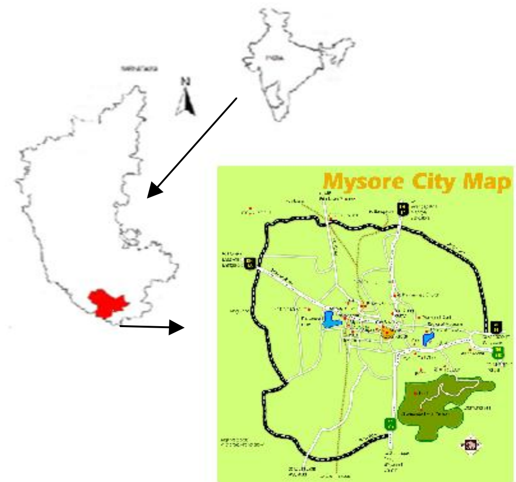

Fig. 1. Picture showing study area

Mysore district is located between latitude 11°45' to 12°40' N and longitude 75°57' to 77°15' E and the city is located at 12.30°N 76.65°E (Fig 1). Mysore has a semi-arid climate. The temperature in the city normally varies from 13^0C in winters to 37^0C in summers. The city is rapidly expanding and lies at the base of the Chamundi Hills on the undulating table land and has an average altitude of 770 metres. Geologically, the area is largely made up of granitic gneisses with amphibolitic bodies and pegmatites. The region is covered largely with red sandy soil. The annual mean precipitation for Mysore city is 800 mm. The city is located in the interfluves of the Cauvery River which flows through the north of the city and the Kabini River, a tributary of the Kaveri, lies to the south. Drinking water for some parts of Mysore city is sourced from the Kaveri and Kabini rivers. Municipal water supply in Mysore city is of three kinds: treated Cauvery/Kapila river water, groundwater and a mix of surface water and groundwater. The city has an underground drainage system built in 1904. The sewage waste from the city drains into four valleys: Kesare, Malalavadi, Dalavai and Belavatha [5]. Sanitation and water supply in the city is managed by the Mysore City Corporation. Mysore city has around nine lakh inhabitants, spreading across an area of 128.42 km^2. As a consequence of population growth, Mysore Urban Development Authority (MUDA) is developing and constructing new layouts and roads. In addition to this, many private developers have created new layouts.

II. MATERIALS AND METHODS

Field sampling was done in the pre-monsoon (PRM) season in April, 2011 and in the post-monsoon (POM) season in October, 2011. In each season 53 groundwater samples were randomly collected throughout the city. Groundwater samples were collected in 1 liter plastic containers and prior to collection as part of our quality control measures all the bottles were washed with non-ionic detergent and rinsed with de-ionized water. Before the final water sampling was done, the bottles were rinsed three times with the well water at the point of collection. Each bottle was labeled according to sampling location and all the samples were preserved at 4ºC after being transported to the laboratory. The samples were analyzed

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using standard procedures of APHA [6]. pH, EC and TDS were measured on spot using a waterproof PCSTestr -35, Ca and Mg were analyzed titrimetrically using EDTA method, Na and K were determined by flame photometry. HCO_3 and Cl were estimated by titrimetric method. SO_4 was determined using Nephelometer and NO_3 was determined by UV spectrophotometer. From the analyzed results geochemical facies type and WQI were determined.

III. RESULTS AND DISCUSSION

Physico-chemical characteristics of groundwater samples are presented in Table 1. Table 2 represents the results compared with the Bureau of Indian Standards (BIS) [7] and World Health Organization Standards (WHO) [8] with the percent compliance to assess the quality of groundwater in Mysore city for drinking purposes. Groundwater was slightly alkaline in nature showing pH of 7.88-8.71 and 7.55-8.71 during PRM and POM seasons respectively. 21% and 20% of samples of PRM and POM seasons respectively with regard to their EC, TH, Na, K, SO_4 and NO_3 parameters were ranging out of BIS standard but as compared to the WHO standard, all samples were within permissible limits. pH has no direct adverse effects on health; however, higher values of pH hasten the scale formation in water heating apparatus and high pH induces the formation of trihalomethane which is toxic [9].

Electrical conductivity values indicate the amount of dissolved chemicals in water and the presence of Na, K and Cl. In the present study, conductivity ranges were from 315-1513µs/cm and 288- 1306 µs/cm during PRM and POM respectively. The elevated values of EC in PRM season indicated inorganic pollution of the water samples. For total dissolved solids, 64 % of samples in PRM season and 47 % of samples in POM season were out of the prescribed standards of both BIS and WHO. Total hardness ranges from 91-355 mg/L in PRM season with 4% of samples exceeding permissible limits and 90-340 mg/L in POM season with 2% of samples exceeding threshold range for both BIS and WHO standards.

Hardness is an indication of deposits of Ca and Mg ions. Ca and Mg ions concentration were measured separately. 34% and 64% of samples exceeded Bureau of Indian standards in PRM and POM seasons respectively, whereas 15% of samples exceeded WHO limits in PRM season and in POM season all samples were within the range. Compared to Ca, more number of samples was out of range for Mg concentration, 88% in PRM and 90% in POM for BIS, all samples were within the range for WHO standards. NO_3 concentration was relatively very high in POM i.e., 60% and 58% of samples were out of range for BIS and WHO standards respectively. Nitrate, the most highly oxidized form of nitrogen compounds is commonly present in surface and groundwater because it is the end product of the aerobic decomposition of organic nitrogenous matter. Cl values ranged from 71-298 mg/L and 56.8-262.7 mg/L for the respective PRM and POM seasons. 9% in PRM and 3% of samples in POM exceeded the range for both BIS and WHO standards. Chlorides connote the presence of weathered silicate rich rocks beneath the overburden and leaching from soil due to infiltration from the landfill and other anthropogenic activities. This agreed with the findings of [10] & [11]. Na, K and SO_4 values were within the prescribed limits of both BIS and WHO standards.

Parameters	PRM (n=53)			POM (n=53)		
	Min	Max	Std. Dev	Min	Max	Std. Dev
pH	7.88	8.71	0.195522	7.55	8.71	0.228697
EC(µs/cm)	315	1513	261.2926	288	1306	231.9832
TH(mg/l)	91	353	61.46656	90	340	42.87559
TDS (mg/l)	1.07	869	185.0999	207	927	164.7745
Ca^{2+}(mg/l)	29	145	28.44569	16	88	16.96408
Mg^{2+}(mg/l)	17	101	22.72505	15	141	24.85308
Na^{+}(mg/l)	3.3	10.5	1.898139	5	77	22.13824
K^{+}(mg/l)	0.1	10.7	1.456351	1	12	1.977519

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CO_3^{2-}(mg/l)	20	140	25.82176	50	100	26.4287
HCO_3^- (mg/l)	160	740	114.3252	150	500	72.98329
SO_4^{2-}(mg/l)	0.3	30	6.808919	0.2	15.3	3.170801
Cl^-(mg/l)	71	298	51.12469	56.8	262.7	44.69197
NO_3^- (mg/l)	19.32	77.28	17.24705	9.2	423.2	89.82689

Table 1.Characteristics of chemical parameters in groundwater of Mysore City during PRM and POM seasons.

Parameters	BIS	PRM (% of samples out of PL)	POM (% of samples out of PL)	WHO	PRM (% of samples out of PL)	POM (% of samples out of PL)
pH	7.0- 8.5	21	20	6.5-9.2	WPL	WPL
EC(µs/cm)	-	-	-	400	87	89
TDS(mg/l)	500	64	47	500	64	47
TH(mg/l)	300	4	2	300	4	2
Ca(mg/l)	75	34	6	100	15	WPL
Mg(mg/l)	30	88	90	150	WPL	WPL
Na(mg/l)	-	-	-	200	WPL	WPL
K(mg/l)	13	WPL	WPL	200	WPL	WPL
NO_3(mg/l)	45	6	60	50	6	58
SO_4(mg/l)	150	WPL	WPL	200	WPL	WPL
PO_4(mg/l)	-	-	-	-	-	-
Cl(mg/l)	250	9	3	250	9	3

Table 2 Groundwater results showing percentage of samples out of permissible limits when compared with BIS and WHO standards.
(*PL: Permissible limits)

A. Piper Diagram

Hydrochemical concepts can help to elucidate mechanisms of flow and transport in groundwater systems, and unlock an archive of paleoenvironmental information [12], [13] & [14]. Hill piper plot [15] is used to infer hydrogeochemical facies of groundwater. In the pre-monsoon season, a majority of the water samples fell in mixed Mg-HCO_3 type, with minor representations from mixed Ca-Mg-HCO_3-Cl. In the post monsoon season, a majority of water samples fell in mixed Mg-HCO_3-Cl type. In both seasons, alkalines (Ca and Mg) exceeds alkalis (Na and K) and weak acid (HCO_3) exceeds strong acids (Cl and SO_4).Fig 3.1.

Fig 3.1 Hydrogeochemical facies of groundwater samples .

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B. Calculation of Water Quality Index (WQI)

WQI is defined as a technique of rating that provides the composite influence of individual water quality parameters on the overall quality of water for human consumption [16]. WQI is an important parameter for demarcating groundwater quality and its suitability for drinking purposes [17], [18], [19], [20], [21] & [22]. In this study, in order to calculate the water quality index groundwater chemistry has been utilized as a tool to stance water quality for drinking purposes. The standards recommended by WHO (2004) and BIS 110002 (2003) for drinking water purposes have been utilized to calculate WQI. To compute WQI, selected parameters has been assigned weight (wi) based on its relative importance in the overall quality of water for drinking purposes. From the assigned weight, relative weight (Wi) is calculated from the following equation:

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

Where
Wi - relative weight
wi - parameter weight
n - number of parameters

Chemical parameters	Indian Standard (BIS 110002, 2003)	Weight	Relative weight
pH	6.5-8.5	9	0.2190
TDS	500	5	0.1160
TH	300	0.2	0.0062
Calcium	75	3	0.0700
Magnesium	30	3	0.0700
chloride	250	5	0.1160
Nitrate	45	5	0.1160
Sulphate	200	5	0.1160
Bicarbonate	300	1	0.0230
Potassium	13	2	0.0470

Table 3. Relative weight of chemical parameters.

Computed relative weight (Wi) values of each parameter are given in Table 3. For each parameter, quality rating scale (qi) is assigned by dividing each water sample concentration by its respective standard as mentioned in the guidelines of BIS 110002 (2003) and the result is multiplied by 100.

$$q_i = (C_i/S_i) \times 100$$

Where
Qi - quality rating
Ci - each analyzed chemical parameter concentration present in each water sample in mg/L.
Si - is drinking water standard for each chemical parameter in mg/L as per BIS (2003) guidelines.

To compute WQI, Sub Index (SI) is first determined for each chemical parameter, and then the same is used to determine the WQI by the subsequent equation.

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$$SI = W_i \times q_i \text{ (relative weight x quality rating)}$$

$$WQI = \Sigma SI_i.$$

Range	Type of water
< 40	Excellent water
41 - 80	Good water
81 - 160	Poor water
161 - 320	Very poor water
>320	Incompatible water for drinking purposes

Table 4. Water quality type based on WQI ranges

The computed WQI values ranged from 42.61 – 109.51 and 39.82 – 166.19 for PRM and POM seasons respectively. Based on the WQI results water types were assigned in Table 4. Most of the values in the table exceed the permissible limits of both BIS and WHO standards. Individual water samples WQI results are represented in Table 5.

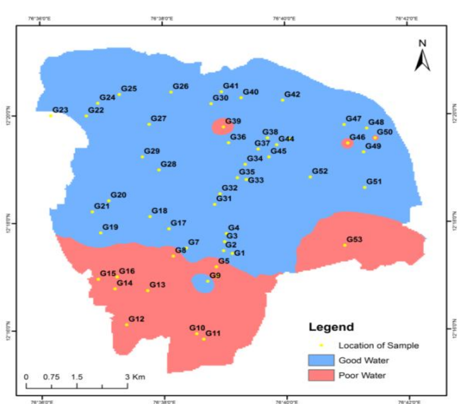
S.no	PRM	WQI. C	POM	WQI. C	S.no	PRM	WQI. C	POM	WQI. C
1	68.84	Good Water	39.82	Good Water	28	45.00	Good Water	106.32	Poor Water
2	72.14	Good Water	54.53	Good Water	29	42.61	Good Water	92.87	Poor Water
3	62.67	Good Water	61.46	Good Water	30	63.20	Good Water	96.30	Poor Water
4	77.53	Good Water	55.95	Good Water	31	53.26	Good Water	113.63	Poor Water
5	94.01	Poor Water	73.96	Good Water	32	52.47	Good Water	139.08	Poor Water
6	101.22	Poor Water	73.01	Good Water	33	59.63	Good Water	71.98	Good Water
7	70.98	Good Water	88.51	Poor Water	34	44.01	Good Water	109.07	Poor Water
8	90.10	Poor Water	59.28	Good Water	35	54.84	Good Water	115.14	Poor Water
9	67.85	Good Water	59.46	Good Water	36	71.41	Good Water	113.54	Poor Water
10	100.08	Poor Water	75.64	Good Water	37	69.12	Good Water	137.78	Poor Water
11	96.93	Poor Water	71.02	Good Water	38	65.34	Good Water	107.91	Poor Water
12	98.58	Poor Water	97.70	Poor Water	39	94.08	Poor Water	106.02	Poor Water
13	99.84	Poor Water	92.40	Poor Water	40	43.59	Good Water	119.45	Poor Water
14	82.94	Poor Water	76.44	Good Water	41	67.58	Good Water	115.75	Poor Water
15	96.92	Poor Water	64.65	Good Water	42	61.59	Good Water	87.81	Poor Water
16	94.40	Poor Water	96.14	Poor Water	43	53.77	Good Water	104.19	Poor Water
17	63.04	Good Water	60.82	Good Water	44	79.21	Poor Water	114.71	Poor Water
18	79.97	Poor Water	79.77	Poor Water	45	71.98	Good Water	102.56	Poor Water
19	72.71	Good Water	85.81	Poor Water	46	82.76	Poor Water	117.43	Poor Water
20	72.62	Good Water	82.36	Poor Water	47	67.52	Good Water	85.32	Poor Water
21	78.20	Good Water	67.25	Good Water	48	72.46	Good Water	106.36	Poor Water
22	57.10	Good Water	166.19	Very Poor	49	75.95	Good Water	116.27	Poor Water

				Water					
23	79.12	Poor Water	114.41	Poor Water	50	80.71	Poor Water	115.13	Poor Water
24	68.12	Good Water	115.15	Poor Water	51	73.79	Good Water	109.33	Poor Water
25	68.74	Good Water	108.55	Poor Water	52	61.32	Good Water	104.88	Poor Water
26	73.32	Good Water	121.85	Poor Water	53	109.51	Poor Water	118.49	Poor Water
27	44.39	Good Water	114.61	Poor Water					

Table 5. WQI results of Individual water samples. (* WQI. C - Water quality index classification)

C. *Thematic Maps*

Thematic maps were drawn to show the water quality type of samples (Fig 3 Thematic maps showing WQI for PRM and POM seasons). During PRM season 68% of samples indicate “Good water” and 32% of samples represent “Poor water”. During POM season 28% constitute “Good water” type, 70% represent “Poor water” type and 2% of samples indicated “Very poor water” quality type. In the POM season, a greater number of samples (70%) illustrated poor water type as compared to PRM season.



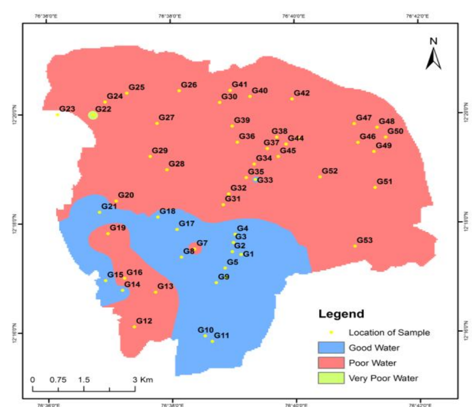


Fig 3 Thematic maps showing WQI for PRM and POM seasons.

V. CONCLUSION

Calculation of Water Quality Index gives a realistic picture of the water types based on the analyses performed. The present study revealed that in the PRM season 68% of samples were of “good water type” and in the POM season 70% of the samples were of “poor water type”. This gives the exact picture of the water quality season-wise. Runoff plays a major role especially in urban areas, which carry pollutants from the surface to the groundwater through the soil media. The high value of WQI in the POM season is due to the lofty values of Total dissolved solids, Magnesium and Nitrate. Considering the present study results, the water is required to undergo some extent of treatment before consumption.

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