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Groundwater Quality Evaluation by Physicochemical Characterization and Water Quality Index for Nanded Tehsil, Maharashtra, India

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Abstract. Groundwater is an essential natural resource constituent of our life support system, where, it is used for drinking and irrigation purpose. An attempt has been made to recognize the hydro chemical characteristics of groundwater to develop water quality index model (WQI) in Nanded Tehsil. A total of 50 representative groundwater samples were collected from dug/bore wells during post-monsoon 2012 and analyzed for major cations and anions. The groundwater quality were assessed by different physicochemical parameters such as pH, electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), carbonate (CO^{-}_{3}), bicarbonate (HCO^{-}_{3}), chloride (Cl^{-}), nitrate (NO_3^{-}), sulphate (SO_4^{-}) and phosphate (PO_4^{-}). The Hydrochemical results were compared with Indian standards (BIS) which illustrate that TDS (16%), TH (22%), Ca (2%), Cl (2%) and Na (12%) samples exceeds the permissible limits. Water quality index (WQI) used to classify water quality as excellent, good, poor, and unsuitable categories. WQI shows that 34% samples are excellent, 60% samples are good and 6% unsuitable for drinking purpose. The groundwater samples 12, 40 and 44, fall in an industrialized and urbanized area shows unsuitable type of water for drinking. Through clutching hydro chemical investigation, GIS based IDW technique was used to signify the spatial variation of WQI in Nanded Tehsil.

Keywords: groundwater, Water Quality Index, GIS, Nanded

1. Introduction

Groundwater is an important natural resource for drinking water particularly in rural areas of many counties like India. Poor drinking water quality leads to extensive acute and chronic diseases and, in many countries is a major cause of death [1]. In the world, quality of water resources is being gradually more degraded as a consequence of its intensified anthropogenic exploitation [2]. Generally, groundwater quality and quantity is distorted due to overexploitation and human induced activities. Once, the groundwater is polluted, the restoration of such water is still remained a major challenge, therefore, it is crucial to develop the water quality monitoring system for fitness of water for different purposes. Groundwater quality is mainly defined in terms of its physical, chemical and biological characteristics for drinking. Naturally, groundwater quality depends on geological and geochemical composition of rocks, residence time of water, dissolution and precipitation of minerals, oxidation reduction reactions and environmental conditions in the study area.

The water quality index (WQI) is most important tool to assess the water quality which is extensively helpful to researcher and policy makers for the sustainable management of groundwater resources. The WQI

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was initially suggested by Horton [3]. The WQI provides a single numerical digit by integrating water quality parameters with respective regulatory standards, which understand the list of constituents and their concentration present in water [4]-[6]. The objective of the present study is to perform the groundwater quality evaluation based on physicochemical characteristics and WQI method. It also aims to generate WQI map to represent its spatial distribution by using GIS based IDW technique for Nanded Tehsil, Maharashtra

2. Study Area

Nanded Tehsil is administrative block of Nanded District located in South Eastern Part of Deccan Volcanic Province of Marathwada region of Maharashtra state. The study area is located between latitudes 19^0 3' N to 19^0 17'N and longitude 77^0 10' E to 77^0 25' E (Fig. 1). The study area comprises with semi arid region and tropical climate. The temperature of study area is ranging from 13 to 46 ^{0}C. The average rainfall of the study area is 900 mm, where, 88 % rain receives under the influence of South West Monsoonal winds. Godavari River flows in South West to South East direction having alluvial plain along its coast in the study area. The thickness of alluvium varies at different places and maximum 20 m encountered in flood plain areas of rivers. The study area is principally irrigated by Godavari and its sub-tributary Asna River and also left bank canal taking off water from Siddheshwar dam of the Purna project, of Parbhani district. The North East part of the study area is the convergence point of Asna and Godavari River. The study area underlain by geological formation mainly Deccan Basalt flows of vesicular, amygdaloidal, weathered, fractured basalt etc. Black cotton soil and loamy to sandy soil are main soil types covering the study area. The soil has high productivity value for the crops like Cotton, Jawar, Soyabean etc due to rich in plant nutrients.

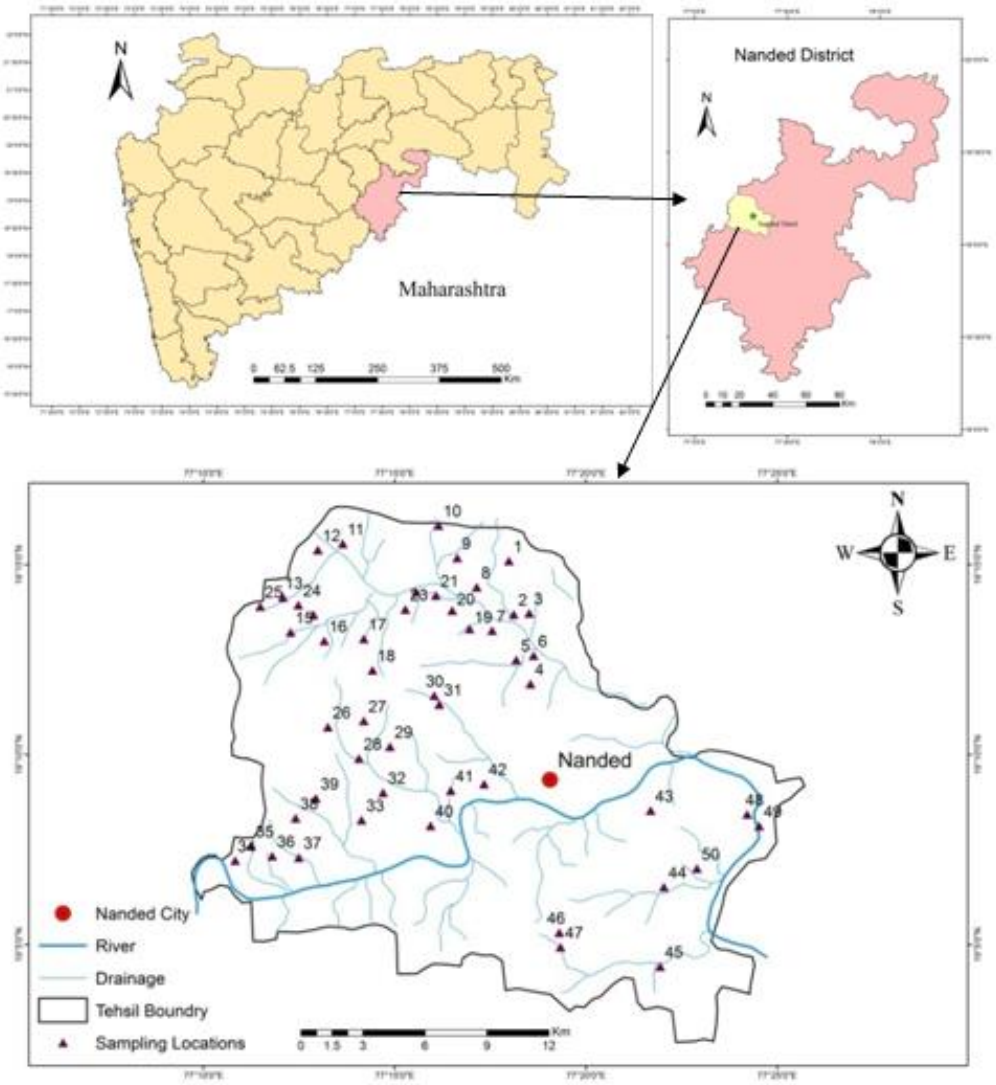

Fig. 1: Study Area Map with sample locations

3. Material and Methodology

In order to understand the physicochemical composition of groundwater, a detailed field survey was carried out in Nanded Tehsil. A total fifty (50) representative groundwater samples were collected from different dug wells and bore wells for the period of post-monsoon season 2012 in the study area. Survey of India, Toposheet no's 56 E/5, 56 E/8, 1:50,000 scales were used for the preparation of water quality index map of the study area. The groundwater samples were collected in pre-washed one-litre polyethylene cans after pumping the wells for 5-10 minutes; afterwards these cans were properly sealed, labelled and brought to laboratory for further physicochemical analysis. Location coordinates were recorded by using GPS device. pH and Electrical conductivity measured in the field itself by using portable digital meter. The physicochemical parameters like calcium, magnesium carbonate, bicarbonate and chloride were analyzed in the laboratory by gravimetric analysis following the standard methods of American Public Health Association [7]. The sodium and potassium ions were determined by flame photometer (Elico CL 361). The sulphate, phosphate, and nitrate were determined by using spectrophotometer (Shimadzu UV-1800). The Arc GIS 9.3 software was used for the preparation of water quality index maps of the study area.

4. Water Quality Index (WQI)

Water Quality Index (WQI) is a technique of rating that provides the composite influence of individual water quality parameters on the overall quality of water for human consumption [8]. It is computed in three steps [3], [9]. In first step the weight is assigned to each parameter according their relevance to drinking quality of water. The maximum weight of 5 is assigned to parameters like Total dissolved solids (TDS), Chloride (Cl) and Nitrate (NO_3) because of their significant role in water quality evaluation. The parameters like pH, Total Hardness (TH), Sodium (Na) and Sulphate (SO_4) were assigned with weight 3. The Weight 2 is assigned for Calcium (Ca), Magnesium (Mg), Potassium (K), Carbonate (CO_3), Bicarbonate (HCO_3) and Phosphate (PO_4) due to their less significant role [10], [11]. Second step is calculation of relative weight (RWi) (Table I), computed with the help of eq. No. 1. The third step is quality rating scale (qi) calculation based on dividing the parameter concentration in each water sample by its respective standard [12] multiplied by 100 and it's computed with the help of eq. No. 2. The Wi and qi are used to calculate the Sub index SIi of each parameter following eq. No. 3. Finally, the water quality index (WQI) is calculated from eq. No. 4.

$$RWi = Awi / \sum AWi \quad (1)$$

Where, RWi = Relative weight,
AWi = Assigned Weight
n = Number of parameters

The quality rating scale for each parameter is calculated with the following equation

$$qi = (ci/si)*100 \quad (2)$$

Where, qi = Quality rating for i^{th} parameter
ci = Concentration of i^{th} chemical parameter of water sample (mg/l)
si = permissible standard for i^{th} parameter set by BIS

Sub index (SIi) for each parameter is determined by equation 3 and final WQI is calculated by following equation 4

$$(SIi = RWi * qi) \quad (3)$$

Where, SIi = sub index of i^{th} parameter
qi = rating based on concentration of i^{th} parameter

$$WQI = \sum SIi \quad (4)$$

Table I: Relative weight of each water parameter [16]

Parameters	pH	TDS	TH	Ca	Mg	Na	K	CO_3	HCO_3	Cl	NO_3	SO_4	PO_4	Total
Weight (Wi)	3	5	3	2	2	3	2	2	2	5	5	3	2	39
Relative weight (RWi)	0.077	0.128	0.077	0.051	0.051	0.077	0.051	0.051	0.051	0.128	0.128	0.077	0.051	1
BIS Standards (1998)	8.5	2000	300	75	30	100	10	--	200	250	45	200	--	

5. Result and Discussion

5.1. Groundwater Quality Assessment

The descriptive statistics including minimum, maximum, average and standard deviation of the groundwater samples collected during post-monsoon 2012 are tabulated in Table II. A total 14 physicochemical parameters were assessed to evaluate the groundwater suitability for drinking purpose. Analytical results for all the physicochemical parameters were compared with BIS [12] standards, shows that the average pH value in study area is 8.3 which is slightly alkaline where, 6 samples i.e., 12 % are above the permissible limit. The pH of water is most decisive factor in the determination of wastewater treatment processes like coagulation, water softening, disinfection etc. The high pH value is causes the corrosion of metal pipes. In the study area 16 % samples surpass the permissible limit (2000 mg/l) of TDS. Such, high concentration of TDS in groundwater is due to leaching of salts from soil and anthropogenic activities, which leads to corrosion of metals.

Table II: Descriptive Statistics of groundwater quality parameters (n = 50)

	pH	EC	TDS	TH	Ca	Mg	Na	K	CO_3	HCO_3	Cl	NO_3	SO_4	PO_4	WQI
Min.	7.8	816	522.2	88	5.6	8.3	17.2	2	0	80	63.9	0.4	3.9	0	38.1
Max.	8.8	64400	41216	946	352.7	81.4	630.2	8.6	80	460	1043.7	7.2	45.6	0.3	398.7
Avg.	8.3	4792.4	3067.1	233.3	36	34.6	107.4	2.7	25	181.4	175.5	3.3	15.7	0.1	74.7
S.D.	0.2	13120.4	8397	135.1	50.5	16.8	112.8	1.3	16.3	71.5	144.4	1.7	10.2	0.1	71

The total hardness of water is depending on the geological conditions present in the aquifer system. When the groundwater is in contact with limestone or dolomite, the hardness value tends to be very high. In the present study area the total hardness ranges from 88.0 to 946.0 mg/l with an average of 233.3 mg/l. It was found that TH value in all groundwater samples are within permissible limit except sample no. 44 (946.0 mg/l). The sample no. 44 is located close to Tuppa industrial area and quality affected due to the percolation untreated effluent or leaching of minerals. In the study area only 2 % samples exceed the permissible limit of Calcium which may be due to erosion of parent rock material such as limestone and dolomite. Sodium in groundwater ranges from 17.2 to 630.2 mg/l, where, 12 % samples exceed the permissible limit. Generally, the sodium salts occur in groundwater due to rock weathering or dissolution of soil salts stored by the influence of evaporation and it also, indicates its high solubility behaviour [13]. In humans, the high ingestion of sodium causes high blood pressure, arteriosclerosis, odema and hyperosmolarity etc [14]. The high chloride concentration was found in sample no. 44 which is far beyond the permissible limit. The main source of chloride in an urban environment is human excreta particularly urine. Consumption of such high chloride content water affects on taste, indigestion, corrosion and palatability, which also leads to heart and kidney related diseases [15]. It is observed that the values of Magnesium, Potassium, Carbonate, Bicarbonate, Sulphate and Phosphate are within permissible limit.

5.2. Spatial Distribution of Water Quality Index

The groundwater quality of Nanded tehsil for drinking purpose was evaluated through water quality index method. The water quality index values were interpolated in Arc GIS using IDW technique for preparation of water quality index map of the study area. The map was categorized based on the classification shown in Table III. The water quality index value varies from 38.9 to 398.7 hence; it shows large variation of water quality among the groundwater samples in the study area. The water quality index was classified into four water types, viz. Excellent (0-50.0), Good (50.01-100.0), Poor (100.01-200.0) and unsuitable (> 200.01). It is observed that 34 % groundwater samples found in the North Western and few patches in N-NE and S-SW part of the study area come under excellent water type, due to high elevation area having less dissolution and infiltration. The good water type represents 60 % groundwater samples identified in the study area as shown in Fig. 2, hence; 94 % samples in the study area are fit for drinking. Only 3 groundwater samples (12, 40 and 44), located in central part, S-SE near urban area and one patch in North part of the study area are unsuitable for drinking purpose. The samples are located in the periphery of urban and industrial area, where, leaching and dissolution processes which may affect the groundwater quality.

Table III: Classification of groundwater samples based on Water Quality Index [3]

Category	Water Type	Number of Samples	% of Samples
0-50.0	Excellent	17	34.0
50.01-100.0	Good	30	60.0
100.01-200.0	Poor	--	--
>200.01	Unsuitable	03	6.0
Total		50	100

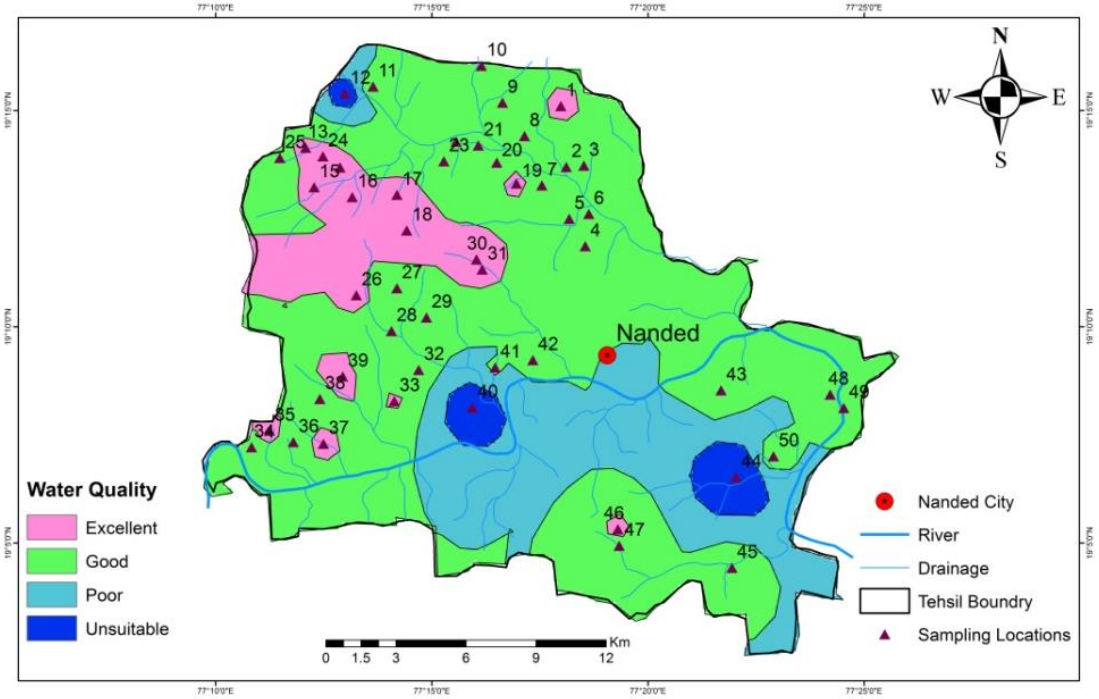

Fig. 2: Spatial distribution of Water Quality Index

6. Conclusion

The present study was carried out to investigate the groundwater quality for drinking purpose in Nanded Tehsil. WQI method has been applied to categorize the different water class and GIS was used to represent its spatial extent in the study area. Analytical results suggests that groundwater in the study area is slightly alkaline and moderately hard to very hard. TDS is found higher in 16 % of groundwater samples, due to the leaching of salts. The concentration of sodium over calcium suggests that cation exchange process taking place in the groundwater at many places in study area. The water quality index of the study area revealed that

majority of the samples belongs to excellent to good water type, hence, fit for drinking. Moreover, only 3 groundwater samples are unsuitable for drinking due to high concentration of TDS, TH and Sodium. The elevated concentration of such parameters is the effect of urbanization and industrialization processes occurring in that particular area. This study suggests that the possible contamination sources of groundwater such as industrial/domestic waste and fertilizers must be controlled by recycling and removal of waste and continuous monitoring to protect this precious resource for future generation.

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