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Comparative study of application of Water Quality Index for the suitability of groundwater quality for drinking purpose: Naregaon dumping site, Aurangabad.

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Abstract: *Water Quality Index (WQI), a technique of rating water quality and analyze the physical, chemical andbiological characteristics of water. It is an effective tool to assessquality and ensure sustainable safe use of water for drinking. Water quality indices aim at giving a single value to thewater quality of a source reducing great amount of parameters into a simpler expression andallows easy interpretation of monitoring data. The present work is aimed to assessthe groundwater quality of Naregaon dumping site of Aurangabad region for knowing the suitability of drinking purpose. Thirty groundwater samples were collected from dug wells for comprehensivephysico-chemical analysis. Twelve parameters were considered for calculating the WQI such as: pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Hardness (TH), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Dissolved oxygen (DO), Chlorides (Cl_4^{2-}), Sulfates (So_4^{2-}), Phosphate (Po_4), Nitrate (No_3^-), and Fluoride (F^-). Water quality index has been calculated by using National Sanitation Foundation-Water Quality Index (NSF-WQI) and Weight Arithmetic Water Quality Index (WAWQI) method. The computed value of WQI ranges from 89.82 to 457.635 by NSF-WQI method and from 26.48 to 1889.92by WAWQI method. It was observed from this study that the main cause of deterioration in water quality was due to the high anthropogenic activities, illegal discharge of solid waste.*

Keywords: *Water Quality Index, Groundwater, Naregaon, dumping site..*

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I. Introduction

The term solid waste as used all- inclusive, encompassing the heterogeneous mass of throwaways from the urban community as well as the more homogeneous accumulation of agricultural, industrial, and mineral wastes. Solid Waste Management has been one of the neglected parts of urban management activities in India. Negative environmental and health impacts from improper solid waste dumping can be easily observed everywhere in the developing world. Open dumping, open burning and un-engineered landfills are common practice throughout the country.

The situation of SWM in Aurangabad metropolis is generally similar to that in many urban centers of less-developed countries. Open dumping and waste transfer in Aurangabad has become part of the local culture of land reclamation, including the infill of excavations, depressions and gullies. Aurangabad city is facing serious environmental degradation and public-health risk due to uncollected disposal of waste on streets and other public areas, clogged drainage system by indiscriminately dumped wastes and by contamination of water resources near uncontrolled dumping sites [1].In Aurangabad, due to a lack of proper planning and funding, the solid waste management scenario is becoming worse day by day. To highlight the main causes of improper solid waste management in developing countries, Aurangabad city is selected as a case study. An improper and inefficient municipal solid waste management system may create serious negative environmental impacts like infectious diseases, land and water pollution, obstruction of drains and loss of biodiversity. The disposal site which was landfill now converted to open dumping ground of about 0.89 hectares receiving around 400 ton of waste daily [2].

The open dumping of solid waste is the most un-scientific method of disposal. It has been found that there are major problems of the open dumping practice. The degradation of the solid waste results in the emission of carbon dioxide (CO_2), methane (CH_4) and other trace gases. The unscientific landfill site may reduce the quality of the drinking water and causes the disease like nausea, jaundice, asthma etc [3].

Groundwater is the important source for drinking and domestic purposes in both rural and urban areas. In the last few decades, there has been a tremendousincrease in the demand for fresh water due to the rapid growth of population and the accelerated pace of industrialization[4]. Groundwater occurs almost everywhere beneaththe earth surface not in a single widespreadaquifer but in thousands of local aquifer systems and compartments that have similar characters[5]. The water should be managed and used carefully and be protected. It is not just a consumer product, it is a precious natural resource, it is vital for both future generation and for our own generation. The life cannot perpetuate without water [6].According to World HealthOrganization (WHO), about 80% of all the diseasesin human beings are caused by water.Water quality is an important environmentalissue worldwide and it depends on a large numberof physicochemical parameters. Regular monitoring of water quality parameters and identification of contaminantsources are essential for providing of safe water [7].Water pollution not only affects water qualitybut also threats human health, economic development,and social prosperity. The most potent threat to the quality of groundwater that has emerged in our country is pollution [8].

A number of indices have beendeveloped to calculate water quality data in an easily expressible and easily understood format.A water quality index is a means to summarize large amounts of water quality data into simple terms (e.g., good) for reporting to management and the public in a regular manner [9] .The water quality index (WQI) which assesses the suitability of waterquality for domestic purposes was adopted [10].WQI is defined as a rating reflecting thecomposite influence of different water quality parameters. WQI is calculated from the pointof view of the suitability of groundwater for human consumption [11].WQI is defined as a rating reflecting the composite influence of various water quality parameters. WQI is calculated from the pointof view of the suitability of groundwater for human consumption [12].A WQI summarizes large amounts of water quality data into simple terms (e.g., excellent, good, bad, etc.) for reporting tomanagers and the public in a consistent manner[13]. Water Quality Index is a numerical expression of the degree of pollution and increasing with the pollution. The WQI provides a comprehensive picture of the qualityof surface or groundwater for most domestic uses and easily understandable for decision makers about quality andpossible uses of any water body [14]. The primary objective of this study is to assess the groundwater quality of the Naregaon dumping site Aurangabad district for its suitability to drinking through WQI.

II. Materials and Methods

2.1 Study Area-

Aurangabad city is located at coordinate 19°52′ 34″ N and 75°20′35″ E with an area 139 km^2. The population of the city was 8,72,663 as per the census of 2001 whereas as per the census of 2011 the population was 11,71,330. Average annual precipitation is about 741 mm. It has an average elevation of 568 meters (1969 feet). The Temperature variation in the city ranges from 37°C to 21°C in summer and 24°C to 13°C in winter. The dumping site at Naregaon is situated 6 kilometers away from city limits. The total area of Naregaon waste dumping site is about 46 acres. The site is non engineered open dump, look like a huge heap of waste . Trucks from different part of city collect and bring waste to this site and dump the waste in an irregular fashion . It is situated at latitude 19°54′15″ N and longitude 75°23′45″ E. Landfilling dumpsite is surrounded by residential areas.

2.2 Materials and Methods-

The groundwater samples were collected from different thirty sampling sites nearby the dumping site (S1 to S30) within two km area using stratified random sampling method for different physic-chemical and biological characterization. These samples were collected at a varying distance to measure and compare the effect of contaminants on the underground water. The well locations were collected by using handheld GPS (Germin ETREX 30X model). The general suitable technique for the preservation of samples followed as per Indian standard methods. This study examined twenty five (25) parameters of physical and chemical namely: pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Hardness (TH), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Dissolved oxygen (DO), Chlorides (Cl_4^{2-}), Sulfates (So_4^{2-}), Phosphate (Po_4), Nitrate (No_3^-), and Fluoride (F^-). Electrical conductivity (EC) and pH values were measured in the field using a portable conductivity and pH meter respectively.

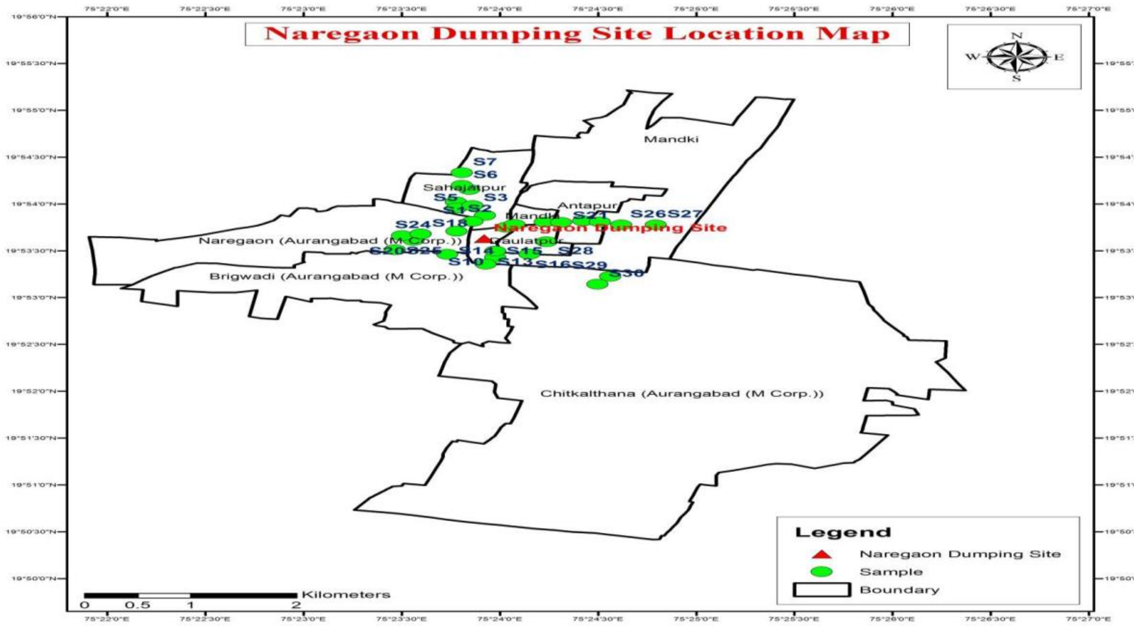

Figure 1: Map showing Sampling locations and dumpsite

2.3 Water Quality Index-

WQI indicates the quality of water in terms of index number which represents overall quality of water for any intended use. It is defined as a rating reflecting the composite influence of different water quality parameters were taken into consideration for the calculation of water Quality index (WQI). The concept of WQI was firstly used by Horton (1965), and then developed by Brown et.al.1970) and further improved by Deininger (Scottish Development Department, 1975). The indices are the most effective ways to communicate the information on water quality trends to the general public or to the policy makers and in water quality management. For assessing the suitability of drinking water, the water quality data of the analyzed samples were compared with the prescribed drinking water standard of BIS 2003 (IS:10500) have been considered for the calculation of WQI.WQI indices are broadly classified into two types, they are physico-chemical and biological indices. The physico-chemical indices are based on the values of various physico-chemical parameters in a water sample.

2.3.1 National Sanitation Foundation Water Quality Index (NSFWQI)

In computing WQI three steps were followed.

i) In the first step, all the twelve parameters has been assigned a weight (w_i) according to its relative importance in the overall water quality of water for drinking purposes (Table 1). The maximum weight is assigned to Total dissolved solids, Sulfate, Chlorides, Nitrate due to their relative importance in water quality and minimum to phosphate and total hardness as it plays insignificant role in water quality assessment.

ii) In the second step, the relative weight ($W\,i$) is computed from the following equation:

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

Where, wi = Weight assigned to each parameter

W_i = Relative weight of each parameter

iii) The third step, a quality rating scale (q_i) for each parameter is assigned by dividing its concentration in each water sample by its respective standard according to the guidelines laid down in the BIS 10500 (2003) and the result is multiplied by 100.

$$qi = (Ci/Si)\times 100$$

Where, q_i = quality rating scale

C_i = concentration of each parameter in each sample in mg/l.

S_i = standard value of each parameter in mg/l.

For computing the WQI, the SIis first determined for each chemical parameter, which is then used to determine the WQI as per the following equation:

$$SI_i = Wi \times qi$$

$WQI = \Sigma\, SI_i$

Calculated relative weight (W_i) values of each parameter are given in Table 3.

Table. 1: Classification of WQI range and category of water

WQI Range	Category of Water
<50	Excellent water
50-100	Good water
100-200	Poor water
200-300	Very poor water
>300	Unfit for drinking

2.3.2 Weight Arithmetic Water Quality Index (WAWQI)

Calculation of WQI was carried out in this work by Horton's method. This involves four steps

i) In first step, Constant of proportionality is calculated by using equation

$k = [1 / (\mathbf{\Sigma}1/ Sn=1,2,..n)]$

Where, k= Constant of proportionality

Sn= Standard permissible value of nth water quality parameter

ii) In second step, the unit weight (Wn) is calculated using the expression given in equation

$Wn = k / Sn$

Where, Wn= unit weight

iii) In third step, the quality rating (qn) is calculated using the expression given in equation

$qn =100 [Vn-Vio]/[Sn-Vio]$ 6.2

Where, Vn = Estimated value of nth water quality parameter at a given sample location.

Vid = Ideal value for nth parameter in pure water.

(Vid for pH = 7 and 0 for all other parameters)

Sn = Standard permissible value of nth water quality parameter

iv) In the last step , the WQI is calculated by using the expression given in Equation

$WQI= \Sigma qn\, Wn/\Sigma Wn$

Where, qn = Quality rating of nth water quality parameter.

Wn= Unit weight of nth water quality parameter.

Table. 2: Classification of WQI range and category of water

WQI Range	Category of Water
<50	Excellent
50-100	Good
100-200	Poor
200-300	Very poor
>300	Unsuitable for drinking

III. Results and Discussion

Analysis of the physical properties of sampled groundwater in all sample locations , appearance, odour and turbidity were found to be within the WHO standard limit . Temperature ranged between 19.2̊ C – 23.1̊ C below the standard limit of 35̊ C - 40̊ C, indicating the presence of foreign bodies such as active micro-organisms. pH indicates the samples acidity but is actually a measurement of the potential activity of hydrogen ions (H^+) in the sample. The result shows that pH of water sample varies from 6.3 to 8.3 suggesting acid to alkaline nature of water. The acceptable limit for drinking water standard is 6.6 to 8.5. pH was within the acceptable range of 6.5 to 8.5. Conductivity in water is affected by the presence of inorganic dissolved solids like nitrate, sulpate and phosphate anions or cations like sodium, magnesium and iron. The results indicate EC of groundwater varies from 213 µS/cm to 3550 µS/cm. The permissible limit of EC for drinking water is 750 µS/cm to 2250 µS/cm. Except for S1 and S2 all samples are within the permissible limit.

Water Quality category, were determined by using WQI. The computed WQI values by NSFWQI ranging from 89.82 to 457.63. WQI range and category of water can be classified as shown in table 2. The highest values can be calculated from the samples collected from the S2, S10, S13, S14, S15, S16, S25, S28 sampling locations (Table 3). The high value of WQI at these stations has found to be mainly from higher values of TDS, hardness, calcium, magnesium, chlorides, and nitrate. Among all the of the groundwater samples, the percentage (%) of WQI categories Good (14%), Poor (37 %), Very poor (10%), Unfit for drinking (17%) were observed. This indicates that more than half of samples are poor to unfit for drinking.

The computed value of WQI by WAWQI range from 26.48 to 1889.92 and therefore can be categorized into five types "excellent water" to "unsuitable for drinking". There was highest WQI for the sampling sites S2, S10, S13, S14, S15 and mean values are 871.67, 1784.67, 1158.34, 1295.04 and 1889.92 respectively. The high value of WQI at these stations has found to be mainly from higher values of TDS, hardness, calcium, magnesium, chlorides, and nitrate. Therefore, the quality of water at sampling sites S1, S2, S3, S4, S8, S9, S10, S13, S14, S15, S16, S17, S18, S19, S28 was unsuitable (>300) for human uses during the study period. Hence we can conclude from the table that only S11, S26, S30 are excellent in quality. The percentage (%) of WQI categories Excellent (10%), Good (30%), Poor (7 %), Very poor (4%), Unfit for drinking (50%) were observed. From table 4, it can be observed that WQI by both the methods shows almost similar results related to water quality.

Table 3: Relative Weight of chemical parameters

Chemical Parameter	Standard (BIS)	Weight (w_i)	Relative weight (W_i)
pH	8.5	3	0.065217391
Electrical Conductivity	300	4	0.086956522
Total Dissolved Solids	500	5	0.108695652
Total Hardness	200	2	0.043478261
Calcium	75	3	0.065217391
Magnesium	30	3	0.065217391
Dissolved Oxygen	5	4	0.086956522
Chlorides	250	5	0.108695652
Sulfate	200	5	0.108695652
Phosphate	0.1	2	0.043478261
Nitrate	45	5	0.108695652
Fluoride	1	5	0.108695652
		$\Sigma\ w_i = 46$	$\Sigma\ W_i = 1$

All concentration in mg/l, accept pH and EC in µS/cm.

Table 4: Water Quality Index for Groundwater of Naregaon dumping site Aurangabad

Sr. No.	Sample Number	WQI value (NSFWQI)	Sample Description	WQI value (WAWQI)	Sample Description
1	S1	95.52	Good	701.53	Unfit for drinking
2	S2	303.67	Unfit for drinking	871.67	Unfit for drinking
3	S3	117.09	Poor	516.80	Unfit for drinking
4	S4	124.43	Poor	426.99	Unfit for drinking
5	S5	97.47	Good	77.36	Good
6	S6	130.42	Poor	63.78	Good
7	S7	184.76	Poor	94.83	Good
8	S8	294.67	Very poor	880.64	Unfit for drinking
9	S9	159.10	Poor	383.49	Unfit for drinking
10	S10	390.33	Unfit for drinking	1784.67	Unfit for drinking
11	S11	129.28	Poor	35.33	Excellent
12	S12	90.64	Good	209.11	Very poor
13	S13	457.63	Unfit for drinking	1158.34	Unfit for drinking
14	S14	362.57	Unfit for drinking	1295.04	Unfit for drinking
15	S15	440.63	Unfit for drinking	1889.92	Unfit for drinking
16	S16	254.43	Very poor	867.88	Unfit for drinking
17	S17	166.9	Poor	824.90	Unfit for drinking
18	S18	181.7	Poor	620.70	Unfit for drinking
19	S19	204.30	Very poor	567.75	Unfit for drinking
20	S20	153	Poor	190.88	Poor
21	S21	99.75	Good	85.17	Good
22	S22	129.73	Poor	71.51	Good
23	S23	122.37	Poor	62.09	Good
24	S24	145.79	Poor	127.44	Poor
25	S25	249.45	Very poor	92.42	Good
26	S26	112.57	Poor	36.22	Excellent
27	S27	89.82	Good	59.46	Good
28	S28	302.68	Unfit for drinking	331.15	Unfit for drinking
29	S29	129.93	Poor	54.27	Good
30	S30	95.52	Good	26.48	Excellent

IV. Conclusion

- The concentrations of EC, TDS, TH, calcium, magnesium was high in sampling site near dumping yard. The high concentration of these parameters shows that there is groundwater contamination from leachate percolation in the study area.
- An analysis of the chemistry of 30 dug wells sample indicates it is generally unsuitable for drinking purposes, except some locations.
- The overall WQI shows 22 % of water samples are the good category, samples show that the water is suitable for direct consumption while that 60% of groundwater samples were found as poor to unfit for drinking category and cannot be used for direct consumption and requires treatment before its utilization.

Suitable water treatment process such as water softening, ion exchange and reverse osmosis should be used to reduce the concentrations of contaminants in the study area.

- The WQI values indicate that the distance from dumping site increases contamination decreases. Thus it can be concluded that the contamination is due to solid waste dumping.
- AMC should ensure new that new landfills are sited away from residential areas since people in residential areas are mostly dependent on well or bore water.

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