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Water quality index assessment for ground water of Indore City (M.P.), India

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ABSTRACT

It is generally assumed that ground water is safe (free from pathogens) and does not contain harmful constituents. But this belief is not true under all circumstances. The unscientific disposal of human and animal wastes is found to be the main anthropogenic activity that has lead to the contamination of ground water with micro-organisms, nitrates, etc. To check the level of contamination in Indore city, monitoring of ground water quality was carried out for three years from January 2016 to June 2019 from twenty groundwater sources in Indore city. Analysis was carried out for the assessment of 20 parameters including mineral, demand, nutrient, bacteriological and metal analysis. The samples were collected at an interval of every 3 months. The average values of the 14 times analysis were considered for calculating the Water Quality Index. Water Quality Index (WQI) is an index to convert complex data pertaining to water quality into the most comprehensible and simple data that can be understood by general public and policy makers as a whole. The WQI for many of the samples ranges between 25 – 50 indicating its bad quality while for very few of the samples it was between 50 – 70, showing bad to medium water quality. The study revealed that all the groundwater sources studied are contaminated and are unfit for human consumption and requires purification before it is used for drinking and domestic purposes.

Key words: *Ground water, Water Quality Index, Water quality, DO, BOD, etc.*

Introduction

The quality of water is of utmost importance compared to quantity in any water supply planning, and especially for potable purpose purity is the prime requirement. The chemical, physical and bacterial characteristic of groundwater determines its usefulness for municipal, commercial, industrial, agricultural and domestic water usage (Rakesh Kumar Tatawat *et al.,* 2007). Due to lack of proper operation and maintenance, the water supply systems are unable to run at their full capacity (Biswas *et al*., 2007). As fresh water will be a scarce in the future water quality monitoring program is necessary for the protection of fresh water resources (Pesce *et al*., 2000; Malviya *et al*., 2011; Gaikwad *et al.,* 2018).

In order to summarize water quality data in understandable format, number of measures (indices) have been devised. One such index is Water Quality Index (WQI) which was first mathematically developed by Horton as a means of deriving a single value from numerous test results .Similar to Ultra violet index or an air quality index; it can inform us about the potential threat to overall quality of water bodies. This index also helps to compare the data between various locations (Malviya *et al*., 2011;

Gaikwad *et al*., 2018).

Horton 1965 used the arithmetic aggregation function for the WQI. He selected 10 most commonly measured water quality variables for his index including dissolved oxygen (DO), pH, coliforms, specic conductance, alkalinity, and chloride. The arithmetic weighing of the water quality variables was multiplied with the temperature and pollution to obtain the sum aggregation function from which the overall water quality index was found out. Similar to Horton (1965); Brown *et al.* (1970) also employed basic arithmetic weighting, although without the multiplicative variables. This effort was supported by the National Sanitation Foundation (NSF) in which the water quality variables were chosen using the Delphi method, which generates results from the convergence of expert's opinions. The NSF WQI used logarithmic transforms to convert water quality variable results into sub-index values (Ansari and Hemke, 2013; Kosha *et al.,* 2017).

The Water Quality Index (WQI) has been considered as one criterion for drinking water classification based on the use of standard parameters for water characterization. The WQI classification proposed by Department of Environment, Malaysia has been used to assess the quality of major water supply sources indicating the level of pollution (Kosha *et al.,* 2017). The National Sanitation Foundation (NSF) WQI was developed to provide a standardized method for comparing the water quality of various water sources based upon nine water quality parameters i.e. temperature, pH, dissolved oxygen, turbidity, faecal coliform, biochemical oxygen demand, total phosphates, nitrates and total solids. The water quality ranges have been defined as excellent, good, medium, bad and very bad (Gaikwad *et al.,* 2018).

Material and Method

Samples were collected directly in pre-washed and rinsed, polyethylene/glass containers identified for respective parameters. Stipulated procedure was followed for washing of sample containers. Field parameters like Temperature, pH and dissolve oxygen, which are non conservative and could not be preserved, were analyzed immediately after collection as per standard procedure. Samples were analyzed based on the standard procedures of water analysis of bacteriological and physicochemical parameters (Standard Methods for the Examination of Water and Waste Waters, 2012). The sampling stations were selected from different zones and from different directions all over the Indore city (Shivhare *et al.,* 2017). The description of the sampling stations is given in Table 1.

Monitoring of ground water quality was carried out for three years from January 2016 to June 2019 from twenty groundwater sources in Indore city. Analysis was carried out for assessment of 20 parameters including mineral, demand, nutrient, bacteriological and metal analysis. The samples were collected at an interval of every 3 months. The average values of the 14 times analysis were considered for calculating the Water Quality Index. For calculating WQI of ground water selected eight parameters are pH, change in temperature, DO, BOD, Total phosphorus, Nitrate nitrogen and Fecal coliforms.

Determination of Water Quality Index WQI is a numeric expression used to transfer large quantity of water characterization data into a single number, which represents the water quality level (Saanchez *et al.,* 2006; Bordalo, *et.al.,* 2006). WQI is a 100 point scale that summarizes results from a total of nine

Table 1. Description of sampling points.

Sample Code	Location Name	Location	Sample Code	Location Name	Location
GW-1	Palda	22.685228 75.889773	GW-11	Navlakkha	22.698930 75.877483
GW-2	Palasia	22.725116 75.887766	GW-12	Usha Phatak	22.723854 75.862579
GW-3	Bapat	22.75444875.878733	GW-13	Juni Indore	22.709614 75.861852
GW-4	Sanwer Road	22.763026 75.847731	GW-14	Shankar Bagh	22.733257 75.851208
GW-5	Satya Sai Bag colony	22.74215975.847776	GW-15	Sadar Bajar	22.725203 75.852679
GW-6	Bhagirathpura	22.74709675.862496	GW-16	Niranjanpur	22.776728 75.890502
GW-7	Sanyogitagunj	22.707106 75.875101	GW-17	Dhar Road	22.70874975.829324
GW-8	Choithram Mandi	22.682212 75.851711	GW-18	Race Course Road	22.72829575.878791
GW-9	Khajuri Bazar	22.719017 75.854470	GW-19	Nipaniya	22.76370975.905528
GW-10	Moti tabela	22.70664275.852655	GW-20	Air port, Indore	22.72916275.804687

different measurements viz. temperature, pH, dissolved oxygen, turbidity, faecal coliforms, biochemical oxygen demand, total phosphate, nitrates and total solids (Malviya *et al.*, 2011; Gaikwad *et al.*, 2018; Krishan Gopal *et al.*, 2016; Bhardwaj and Verma, 2017; Phadatare and Gawande, 2016). Water quality factors with their corresponding weights are given in the following Table 2.

Table 2. Water Quality Index Calculators

Sr. No.	Factor	Weight
1	Dissolved oxygen	0.17
2	Fecal coliforms	0.16
3	pH	0.11
4	BOD	0.11
5	Temperature change	0.1
6	Total phosphate	0.1
7	Nitrates	0.1
8	Turbidity	0.08
9	Total solids	0.07

The 100 point index has been divided into several ranges corresponding to the general descriptive terms shown below.

Range	Quality
90 – 100	Excellent
70 – 90	Good
50 – 70	Medium
25 – 50	Bad
0 – 25	Very bad

For calculating WQI proposed by NSF an algorithm has to be followed

Step 1 : Calculate the water quality parameter value

Step 2 : Calculate quality value (Q-value) from the value function graph using a calculator (http://www.water- research.net/wterqualityindex/index.htm) for each parameter.

Step 3 : Multiply Q value by weight factor to get parameter sub-index.

Step 4 : Compute the WQI from the sum of sub-indices of parameters by the sum of weight factors for the parameters.

Results and Discussion

The results of analyses (average of 14 readings) for

Table 3. Average analysis data for ground water samples GW-1 to GW-10.

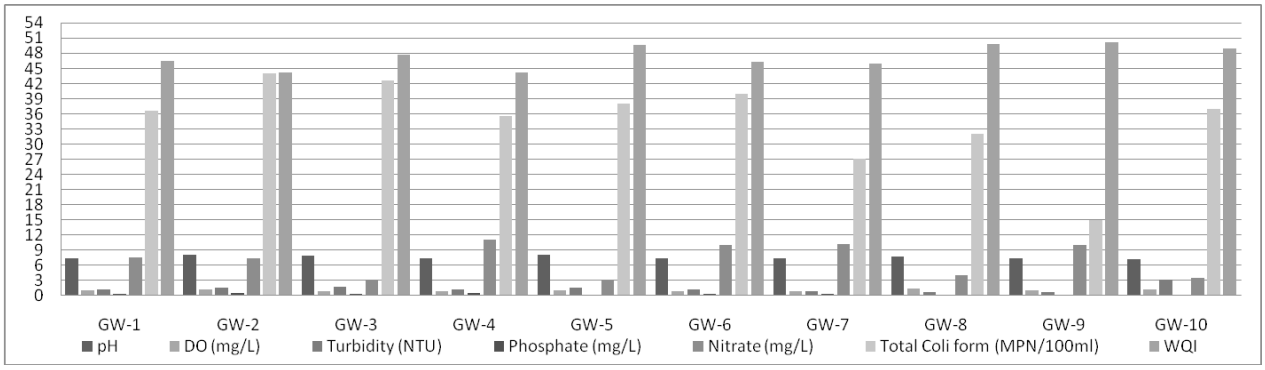
S. No.	Parameters	Unit	GW-1	GW-2	GW-3	GW-4	GW-5	GW-6	GW-7	GW-8	GW-9	GW-10
1	Temperature	°C	24	25	24	24	25	25	24	24	24	25
2	pH	pH Unit	7.36	8.1	8.05	7.35	8.25	7.35	7.4	7.75	7.35	7.25
3	DO	mg/L	1.1	1.2	0.9	0.8	1	0.9	0.8	1.4	1	1.3
4	Turbidity	N.T.U.	1.25	1.65	1.8	1.2	1.55	1.3	0.95	0.65	0.75	3.2
5	Sp. conductivity	µMhos/cm	1105.3	929.3	1027.15	1831.4	1046.9	1497.9	1046	986.45	1493.15	850.75
6	Total Dissolved Solids	mg/L	647	531	505	1310	528	1054.5	656.5	569.5	1149.5	521.5
7	C.O.D.	mg/L	8.5	8	12	15.5	7	13	6	8.5	7.5	5.5
8	B.O.D.	mg/L	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
9	Total Alkalinity	mg/L	350	295	352	375	296	518	404	304	420	420
10	Total Hardness as $CaCO_3$	mg/L	449	288	280	708	98	694	368	190	450	322
11	Calcium	mg/L	92	83.6	85.6	156.8	26.4	145.7	89.6	48	128	80.8
12	Magnesium	mg/L	58.8	18.7	15.81	75.84	7.7	79.2	34.55	16.8	31.2	28.8
13	Chloride	mg/L	133.95	108.05	122.705	361.9	152.5	233.6	119	140	243	64.99
14	Sulphate	mg/L	63.9	62.6	48.905	181.15	42.9	77.2	62.5	61.15	226.9	33.15
15	Phosphate	mg/L	0.234	0.386	0.22	0.431	0.098	0.178	0.256	0.116	0.088	0.154
16	Ammonia	mg/L	0.023	0.01	0.008	0.0025	0.001	0.0045	0.011	BDL	BDL	0.0015
17	Nitrate	mg/L	7.6015	7.3785	3.2105	11.1255	2.9655	10.0595	10.251	4.0715	9.9625	3.5805
18	Fluoride	mg/L	0.7305	0.672	0.837	0.3115	0.4715	1.041	0.504	0.7615	0.7645	0.951
19	Iron	mg/L	0.02	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
20	Total Coli form	MPN/ 100 mL	36.5	44	42.5	35.5	38	40	27	32	15	37
21	Water Quality		46.52	44.16	47.60	44.21	49.65	46.18	45.99	49.84	50.18	48.98
22	Water Quality Index		BAD	BAD	BAD	BAD	BAD	BAD	BAD	BAD	MEDIUM	BAD

20 physico-chemical parameters for all the 20 samples of Indore city are given in Table 3 and 4. The results obtained were cross checked by the use of an automated workbook of water analyses (Bassin, 2007). The respective values for all the 20 parameters were compared with the standard limit recommended by Indian Standards for drinking water (BIS, 2012).

The limits prescribed by the Indian Standards for Drinking Water is there should not be any coliforms in 100 mL sample. The Most Probable Number (MPN count) obtained for all the ground water samples is undesirable. It ranges from 11.5 to 44 MPN/100 mL. The presence of coliform in the ground water is responsible for the bad water quality index.

Conclusion

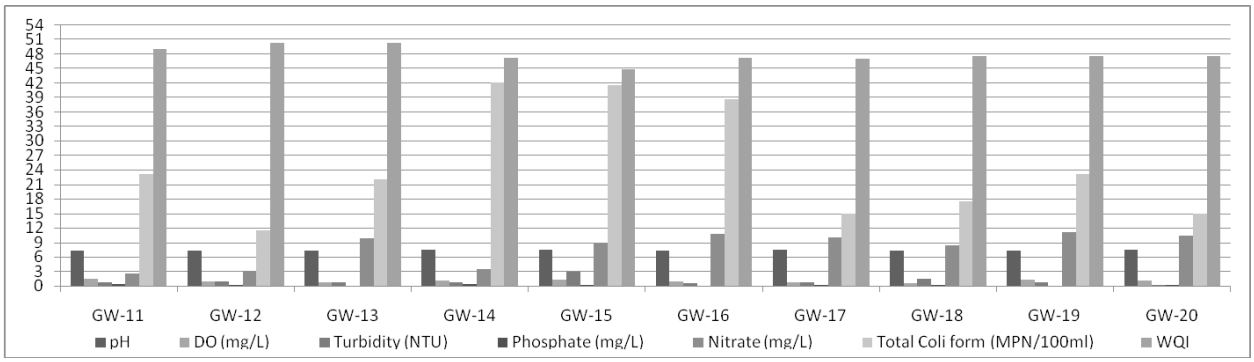
From the results and the graphs 1 and 2 it is clear that the ground water is contaminated and is not fit for drinking without treatment. The WQI calculated



Graph 1. Graphical representation of parameters responsible for WQI in G-1 to G-10 water samples

Table 4. Average analysis data for ground water samples GW-11 to GW-20

S. No.	Parameters	Unit	GW-11	GW-12	GW-13	GW-14	GW-15	GW-16	GW-17	GW-18	GW-19	GW-20
1	Temperature	°C	25	24	24	24	25	25	24	24	24	24
2	pH	pH Unit	7.2	7.3	7.2	7.35	7.5	7.3	7.35	7.35	7.2	7.4
3	DO	mg/L	1.5	0.9	0.8	1.1	1.3	0.9	0.8	0.6	1.3	1.1
4	Turbidity	N.T.U.	0.8	0.95	0.65	0.75	2.85	0.5	0.75	1.4	0.68	0.21
5	Sp. Conductivity	µMhos/cm	781.7	1263.6	1238.45	1350.05	1187.5	1190.4	1493.15	1475.65	1182	1329.3
6	Total Dissolved Solids	mg/L	475.5	692	847	796.5	807	856	1149.5	873	878	963
7	C.O.D.	mg/L	7.5	8	8.5	12	12.5	5	6	8	10	12
8	B.O.D.	mg/L	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
9	Total Alkalinity	mg/L	362	392	552	528	512	328	420	480	460	386
10	Total Hardness as $CaCO_3$	mg/L	300	260	356	592	512	428	450	394	380	520
11	Calcium	mg/L	74.4	78.4	86.4	132	127.2	111.2	128	102.4	92	100
12	Magnesium	mg/L	27.35	15.3	33.6	62.85	46.55	36	31.2	33.1	28	52
13	Chloride	mg/L	53	130	150	136	105	194	241	136	156	131
14	Sulphate	mg/L	17.15	89.8	74.5	27.15	98	129.15	229.9	152.38	128	148
15	Phosphate	mg/L	0.371	0.292	0.076	0.441	0.321	0.118	0.275	0.238	0.148	0.227
16	Ammonia	mg/L	BDL	BDL	0.002	0.005	0.0015	BDL	BDL	BDL	0.002	BDL
17	Nitrate	mg/L	2.569	3.057	9.7665	3.4925	8.7915	10.776	9.9625	8.3265	11.172	10.421
18	Fluoride	mg/L	0.9495	1.0775	0.679	0.379	0.4535	0.689	0.7645	1.0185	0.834	1.005
19	Iron	mg/L	0.012	BDL	BDL	BDL	BDL	BDL	0.002	BDL	0.031	0.007
20	Total Coli form	MPN/100 mL	23	11.5	22	42	41.5	38.5	15	17.5	23	15
21	Water Quality Index		48.95	50.26	50.25	47.07	44.79	47.16	46.98	47.39	47.43	47.49
22	Water Quality		BAD	MEDIUM	MEDIUM	BAD	BAD	BAD	BAD	BAD	BAD	BAD



Graph 2. Graphical representation of parameters responsible for WQI in G-11 to G-20 water samples

is below 50 for nearly all the water samples showing the deteriorated quality of water. The samples falling in the 'Medium' quality range of WQI are very close to the lower limit of the range, i.e. 50.

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