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Drinking Water Quality Assessment Using WQI in Bhokardan Area of Jalna District, Maharashtra State

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Abstract The quality of surface and ground water resources is deteriorating with time due to numerous natural and anthropogenic sources of pollution. As surface and ground water is major source of drinking water in rural area in the study area, made essential to monitor its quality regularly. Water Quality Index (WQI) show a significant role and a useful tool for evaluating the overall quality of water aimed for drinking purpose. This method converts the complex and large data on water quality trends to a single value which can be easily understandable to the common public, local governing bodies and policymakers. In the present research work an attempt was made to check suitability of surface and ground water for drinking purpose using Water Quality Index method. The water quality was estimated by analyzing selected physico-chemical parameters which play significant role in determining water quality such as pH, Alkalinity, Electrical Conductivity, Fluoride, Chloride, Nitrate, Sulphate, Potassium, Total Hardness, E. Coli, Turbidity, Total Dissolved Solids, Dissolved Oxygen and Biochemical Oxygen Demand. Total 32 surface and 35 ground water samples were collected from different selected locations in the study area during pre and post-monsoon seasons respectively. The overall results revealed that almost all the surface water sources from the Bhokardan area, Jalna District, India was found unsuitable for drinking purposes. The application of WQI method to evaluate sequential variations in surface as well as ground water quality was therefore found suitable and effective tool for monitoring and proper management of drinking water resources.

Keywords: *drinking water quality, WQI, Bhokardan area*

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1. Introduction

Surface and groundwater resources are extremely sensitive aquatic systems to pollutants due to their exposure to the various point and non-point sources of pollutions [1]. Exhaustive monitoring surface waters are essential and vital to assure the accessibility of quality water for its various uses [2,3]. The stress on water resources is from various sources and impacts can take different forms. Rapid growth in population resulted in rapid urbanization, industrialization and agricultural development give rise to high adverse impacts on the quality and quantity of water in India [4]. The result of land usage patterns on river water quality was studied in three, different river basins located in Epirus, Northwestern Greece by [5] and observed that, inorganic nutrient load was mostly due to sites that drain agricultural areas. Similar investigation carried out on water quality of the Songhua River in Northeast China by [6] and results showed that the main pollutants was nitrogenous pollutants released from non-point sources. The nitrate appeared as a major problem of safe drinking water in the central region of the India and observed 411 mg/l of nitrate [7]. The main sources of variation in surface water quality are due to both seasonal factors and anthropogenic activities [8].

The WQI provides a single number which expresses the overall state of a particular water body at a particular period after assessing several water parameters for that particular water body [9]. Water Quality Index is a competent technique for evaluating the fitness of water quality for different uses. The assessment of surface and ground water quality can be a complex process undertaking various parameters capable of creating numerous pressures on overall water quality. It is also a very applied and tool for relaying the information on overall quality of water to the layman and concern government, non-government organization local governing bodies [10]. The use of WQI simplifies the presentation of results of investigation associated to a water body, as it summarizes in a single unitless value, the collective effect of several water quality parameters analyzed. The use of water quality index in estimating the quality of surface water bodies such as rivers and lakes have increased tremendously since the initial WQI established by Horton (1965) and upgraded version by [12].

In the rural communities of the Jalna District, agriculture is the main livelihood activity and the backbone of the societies. Climate change is expected to impact agriculture by increasing water demand, limiting crop productivity and resulted into reducing water availability in areas where irrigation is needed [13]. In the present investigation, an attempt has been made to examine the suitability of surface water samples collected along rivers and dams, using the ‘Weighted Arithmetic Index Method’ specified by [12]. The reason for selecting the WAWQI method since it has advantage over other methods such as in this method multiple water quality parameters are combined into a mathematical equation that rates fitness of water body through a number called water quality index as well as it defines the suitability of surface as well as ground water sources for human consumption.

2. Study Area

Bhokardan is one of the taluka situated in the Jalna district. Geographically it is located at 20.250508 °N 75.774236 °E. It has an average elevation of 587 metres and having area of 1273 sq. km. The Location map of the study area is presented in Figure 1. The ancient city lies on minor peaks on the south bank of Kelana river. Keeping in view the present demand and source and sustainable management of water, Central Ground Water Board has categorised Bhokardan taluka as Critical and Semi critical Taluka under the National Aquifer Mapping Programme in India, during XII five-year plan [14]. The rural societies are mainly depending on agricultural and allied activities. The dominant cultivation of cash drop is cotton in combination with a mix of maize, pearl millet (bajra), pulses (tur, mug, uadid) and soybean in the kharif season and sorghum (jowar) and to some degree wheat in the rabi (winter) season [13]. The main surface and ground water uses in the study area is for drinking and agricultural purposes including livestock. Government public open wells are main source of drinking water in the study area.

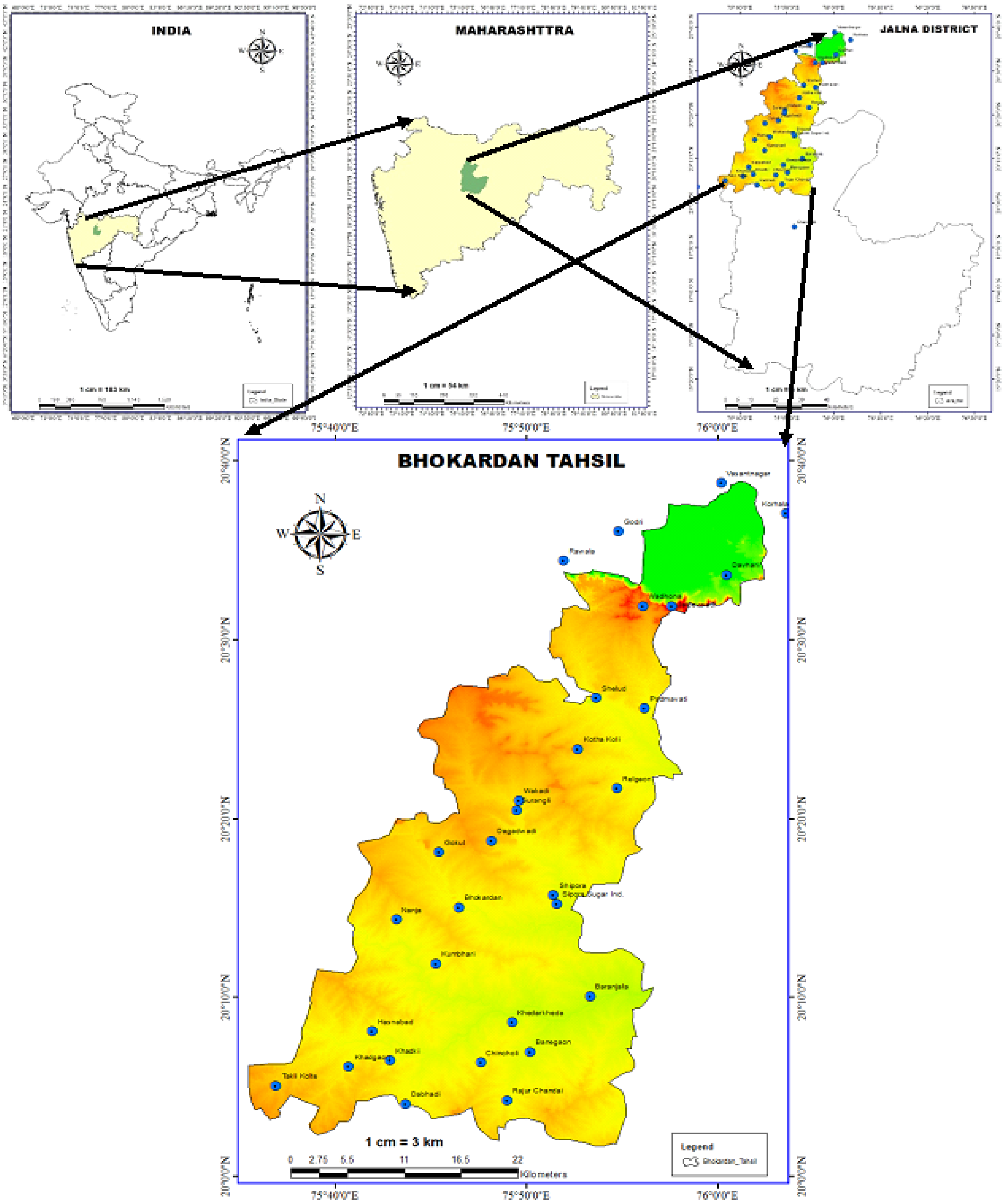

Figure 1. The location map of the study area

3. Materials and Methods

The sampling locations mostly consist of rural areas in this region. Samples were collected at 67 locations preferably of drinking water sources of government owned or identified and private wells for a year. Total 32 and 35 integrated surface and ground water samples were collected respectively during pre and post-monsoon period for the year 2014-2015 and analysed it for various quality parameters like pH, Alkalinity Total hardness, Turbidity, Electrical Conductivity (EC), Chloride, Total Dissolved Solids (TDS), Fluoride, Phosphate, Nitrate, Sulphates Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) using standard methods [15,16]. Samples were collected in two litre capacity plastic cans which were acid washed and pre rinsed with reagent grade distilled water followed by washing with water to be sampled. The methodologies implemented for the determination of water quality parameters of the collected samples Table 1.

Table 1. Water quality parameters and their associated units and analytical method used

Variables	Unit	Analytical methods
Temperature	^0C	Digital thermometer
pH	pH unit	Electrometric
Alkalinity	mg/l	Titration method
Electrical conductivity	µS/cm	Electrometric
Turbidity	NTU	Nepheloturbidity method
Total dissolved solids	mg/l	Electrometric
Total hardness	mg/l	EDTA method
Dissolved oxygen	mg/l	Winkler method
Potassium	mg/l	Flame photometer
Chloride	mg/l	Titrimetric
Sulphate	mg/l	Spectrophotometric
Fluoride	mg/l	Spectrophotometric
Phosphate	mg/l	Spectrophotometric
Nitrate	mg/l	Spectrophotometric
BOD	mg/l	Dichromate method
E. coli	MPN/100	Multiple tube method

Depending on the significant role of the water quality parameters and its corresponding value in the total quality of water for drinking purposes each quality determining parameter has been allocated individual weightage [17]. In the first step, selected 13 water quality parameters which play significant role in assessment of drinking water quality has been allocated a weight (wi) presented in Table 2. The maximum weight of 5 has been allocated to the parameter nitrate, turbidity and E. coli due to its significant role in water quality. Total hardness and potassium which are given the minimum weight of 2 since it may not be harmful to human health. The highest weight allocated is 5 and lowest is 1. In the next step, the relative weight (Wi) is calculated by using the following formula

$$Wi = \frac{wi}{\sum_{i=1}^{n} wi} \quad (1)$$

Where, Wi is the relative weight, wi is the weight of individual quality parameter and n is the number of quality parameters considered for water quality assessment. Calculated relative weight (Wi) values of each parameter are also given in Table 2.

Table 2. Showing weight assigned and relative weight calculated for selected parameters

Parameter	Standards as per BIS & CPCB	wi (Weight)	Wi (Relative weight)
pH	6.5 to 8.5	3	0.063
Total Alkalinity mg/l	200	2	0.042
Turbidity (NTU)	1	5	0.104
Total Hardness mg/l as $CaCO_3$	200	2	0.042
Conductivity (µS/cm)	2000	3	0.063
TDS mg/l	500	4	0.083
Sulphate mg/l	200	4	0.083
Fluoride mg/l	1	5	0.104
Chlorides mg/l	250	3	0.063
Nitrates mg/l	45	5	0.104
Potassium mg/l	10	2	0.042
BOD mg/l	2	5	0.104
E. Coli [MPN/100 ml]	0	5	0.104
		∑ wi=48	∑ Wi=1.000

In the third step, a quality rating scale (qi) for individual quality parameter is calculated by dividing its actual concentration in each water sample by its corresponding standard according to the guidelines laid down in the BIS and the outcome multiplied by 100.

$$qi = \frac{Ci}{Si} * 100 \quad (2)$$

where qi is the quality rating, Ci is the concentration of individual chemical parameter in each water sample in mg/L, and Si is the Indian drinking water standard for each chemical parameter in mg/L according to the guidelines of the BIS 10500, 2012 and Central Pollution Control Board (CPCB).

For estimating the WQI, the SI is first determined for individual quality parameter by multiplying quality rating with relative weight, finally the summation of sub-index is used to determine WQI as per the following formula

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

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

Where, SIi is the sub index of i^{th} parameter; qi is the rating depends on concentration of i^{th} parameter and n is the number of parameters. The calculated WQI values are classified into five types, “Excellent water” to “Water, unsuitable for drinking” as per Table 3.

Table 3. Surface water classification based on Water Quality Index

WQI Value	Water Quality
< 50	Excellent
50-100	Good water
100-200	Poor water
200-300	Very Poor water
>300	Water Unsuitable for drinking

4. Results and Discussions

Surface water is storage of water on the ground or in a stream, river, lake, wetland and ocean. Surface water is naturally refilled by rainfall and naturally vanished through discharge to evaporation, transpiration and sub-surface seepage into the groundwater [18]. The accessibility of surface water in a watershed depends upon the rainfall within the watershed, storing capacity of the particular watershed, porousness of the soil, runoff features of the land, timing and duration of precipitation and the local evaporation rates etc [19]. Surface water quality is a significant factor that decides its usage for drinking and irrigation purposes [20]. Surface water quality monitoring and evaluation has become a critical problem because it affects human and aquatic life [21].

Human health is affected strongly by quality of water [22]. Assessing the quality of groundwater is significant due to its important aspect determining suitability for industrial use, agricultural, domestic, and drinking [23]. The main sources of groundwater pollution such as, agricultural area, landfills, hazardous waste disposal sites, sewerage systems, with high amounts of unabsorbed fertilizers, pesticides and other contaminants [24]. Water quality is affected by natural as well as human induced actions like irrigation, geology and local climate. Due to the enhancement in industrialization and urbanization, quality of groundwater decreases rapidly [25].

As per water quality status reviewed by [26] the overall surface water quality of the Jalna district was poor, which could be due to high Total Dissolved Solids, Fluoride, Sulphate, Nitrate and E-coli concentrations exceeding the permissible limit. In present study following outcomes were observed related to various surface water quality parameters. The physicochemical characteristics of surface and ground water samples in Bhokardan area was statistically analysed and the results such as maximum, minimum, mean and standard deviation parameters are depicted in Table 4 and Table 5. The physical and chemical parameters of the analytical results of surface and groundwater were compared with the standard guideline values recommended by the Bureau of Indian Standards for drinking and public health standards [27].

Table 4. Descriptive statistics of the concentrations of water quality parameters in surface water during pre and post monsoon season

Water Quality Parameter	Units	BIS Drinking Water Standards	Min		Max		Mean		Standard Deviation	
			Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
pH	--	6.5 to 8.5	6.4	5.9	8.2	7.9	7.77	7.46	0.33	0.38
Alkalinity	mg/l	200	98	98	324	287	216.59	193.53	50.98	54.92
Turbidity	NTU	1	5	2	60	59	21.91	9.56	10.85	10.31
TH	mg/l	200	45	33	121	98	69.16	54.50	15.79	14.19
EC	µS/cm	2000	491.1	237.3	1254.8	1792.3	847.81	765.21	183.07	277.87
TDS	mg/l	500	300	253	955	1091	541.59	496.16	154.64	154.61
Sulphate	mg/l	200	75.41	54.56	313.5	205.66	100.49	85.63	42.87	25.03
Fluoride	mg/l	1	0	0	1.1	1.04	0.38	0.38	0.33	0.33
Chloride	mg/l	250	56.2	56.1	480.5	431.8	171.20	145.37	93.18	89.72
Nitrate	mg/l	45	23.5	32.2	178.1	89.3	67.88	52.37	40.19	14.25
Phosphate	mg/l	--	0.13	0.12	8.5	8.46	0.54	0.57	1.45	1.45
Potassium	mg/l	--	3.8	1.5	20.3	29	8.23	8.05	3.62	6.08
BOD	mg/l	--	4.2	3	184.1	213.8	24.00	15.29	36.00	36.81
DO	mg/l	--	0	0	7.5	7.7	5.21	6.33	1.87	1.72
E. Coli	MPN/100ml	0	2	2	46	45	11.31	8.13	9.87	8.51
WQI	--	--	**180**	**135**	**2803**	**3078**	**647.63**	**392.28**	**548.62**	**527.42**

Table 5. Descriptive statistics of the concentrations of water quality parameters in ground water during pre and post monsoon season

Water Quality Parameter	Units	BIS Drinking Water Standards	Min		Max		Mean		Standard Deviation	
			Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
pH	--	6.5 to 8.5	5.9	6.10	8.3	8.1	7.49	7.37	0.42	0.36
Alkalinity	mg/l	200	108	98.00	382	320	240.49	223.49	57.62	54.81
Turbidity	NTU	1	2	0.20	24	20	9.49	2.09	5.24	3.63
TH	mg/l	200	67	60.00	192	134	101.23	88.51	24.84	18.03
EC	µS/cm	2000	726.3	356.70	1714	1778.2	1139.59	941.54	244.94	326.50
TDS	mg/l	500	442	356.00	1124	1082	684.54	593.14	160.65	162.74
Sulphate	mg/l	200	11.50	11.28	139.34	140.46	79.32	77.12	17.13	21.05
Fluoride	mg/l	1	0.05	0.01	1.2	1.3	0.58	0.42	0.33	0.38
Chloride	mg/l	250	76	56.10	521	298.1	221.87	150.57	103.43	68.72
Nitrate	mg/l	45	28.5	22.00	145.67	179.61	55.62	80.61	22.49	44.02
Phosphate	mg/l	--	0.1109	0.10	4.2163	4.2691	0.38	0.35	0.68	0.69
Potassium	mg/l	--	3.7	0.50	20.3	10.9	8.11	3.13	3.68	2.77
E. Coli	MPN/100ml	0	0	0.00	16	26	1.83	3.80	3.73	5.84
WQI	--	--	**80**	**63.00**	**495**	**443**	**198.40**	**132.37**	**94.85**	**96.21**

5. Water Quality Index (WQI)

It was observed that the WQI was very suitable for the categorization of the surface and ground waters monitored [3]. The study carried by showed, the efficiency of water quality index to investigate and understand a dataset for effective evaluation of surface waters [28]. Tyagi & Sharma, 2014 studied of different types of water quality indices, interpreted that the aim of WQI is to recommend a single value to water quality of a source. Besides, interpretation of all important water quality parameters, WQI can reduce many parameters into a simple expression resulting into easy interpretation of water quality monitoring data for better understanding to layman. The WQI results showed that majority of the surface water sample fall under very poor and unsuitable drinking water category. The WQI assessment data significantly depicted that, 97% of the water samples fall within the “Water not suitable for drinking purpose” and only 3% sample fall under “Very poor water” categories, none of the sample exhibited good and excellent quality in the study area during pre-monsoon period while, 31%, 34% and 35% of the water samples were exhibited “Water not suitable for drinking”, “Very poor water” and “Poor water” class respectively. None of the sample exhibited good and excellent quality in the study area during post-monsoon like pre-monsoon period. The surface water quality was observed most worsened during pre-monsoon season as compared to post-monsoon season. Analogues trends were observed by various investigators and their co-investigators in different part of the India [30,33]. The studies carried out by Bora & Goswami, 2017 also revealed similar seasonal trends in surface water quality as of present investigation.

The WQI data of the study revealed that, 17% groundwater sources were of good quality, 40% had poor water quality, 29% exhibited very poor water quality and 14% showed water unsuitable for drinking purpose during pre-monsoon season while 62% groundwater sources were of good quality, 20% had poor water quality, 9% exhibited very poor water quality and 9% showed water unsuitable for drinking purpose during post-monsoon season. The high WQI values in groundwater samples were principally due to the occurrence of higher values of turbidity and E. Coli. The higher concentration of water quality parameters like total dissolved solids, electrical conductivity, total alkalinity, potassium, total hardness, fluoride and chloride also accountable for high WQI values in the study area. None of the location falls under excellent water quality during pre and post-monsoon period. The study showed that the quality of groundwater was found mostly under the category of good water during the post-monsoon season, as compared to that of pre-monsoon season. Similar results were observed by [35].

6. Conclusion

Surface and ground water quality and its suitability for drinking purposes in Bhokardan area has been evaluated. The water quality index data of the present study revealed that majority of the surface water sample fall under very poor and unsuitable drinking water category. The surface water quality was observed highly deteriorated during pre-monsoon season with an average WQI value of 647.6 as compared to post-monsoon season having average WQI value of 392.3. Usually, pre-monsoon samples have higher number of polluted sites. The ground water quality was found most poor during pre-monsoon season with an average WQI value of 198.4 as compared to post-monsoon season having average WQI value of 132.4.

The quality of groundwater was far better during the post-monsoon season, as compared to that of pre-monsoon season. The high WQI values in groundwater samples were principally due to the occurrence of higher values of turbidity and E. Coli. The studies of WQI for both surface and ground water, revealed that almost all the parts of the Bhokardan area, Jalna District, is unsuitable for drinking purpose during both pre and post- monsoon season. Overall analysis outcomes depicted that the agricultural runoff, waste disposal, leaching and traditional methods irrigation are the main reasons of lake water pollution in addition to this some degree of pollution from geogenic origin such as rock weathering. Hence, there is a crucial necessity of appropriate attention and management of surface water resources. The application of WQI to evaluate variations in surface and ground water quality was therefore found suitable and effective tool for monitoring and proper management surface and ground water resources.

Statement of Competing Interests

The authors have no competing interests.

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