International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; SP6: 491-494

(Special Issue -6)
3rd National Conference
On
PROMOTING & REINVIGORATING AGRI-HORTI, TECHNOLOGICAL INNOVATIONS
[PRAGATI-2019]
(14-15 December, 2019)

Evaluation and Comparative Study of Surface Water of Forested Catchment of Three Different Forest Types of Jharkhand using Water Quality Index

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Abstract
The study of surface water in three different forest types i.e. Northern Dry Mixed Deciduous, Dry Peninsular Sal and Moist Deciduous Sal forests has been carried out to assess the water quality for drinking and wildlife propagation. For this purpose, twenty- three surface water samples were collected from small river stream situated in the different forest types. The collected samples were analyzed for pH, temperature, electrical conductivity, total dissolved solids (TDS), total hardness, total alkalinity, major cations (Ca^2, Mg^2), major anions (F^-, Cl^-, NO_3^-, SO_4^{2-}) and dissolved oxygen and biological oxygen demand concentration. The analytical results show mildly acidic water in Northern Dry Mixed Deciduous forest to alkaline water in two other forest types. Water Quality Index (WQI) is one of the most effective tools to communicate information on the quality of any water body. The computed WQI values of Northern Dry Mixed Deciduous forest range from 108.12 to 434.74 with an average value of 187.90, the WQI of Dry Peninsular Sal forest range from 25.15 to 159.25 with an average value of 11.02 and in Moist Deciduous Sal forest the WQI value ranges from 41.06 to 114.79 with an average value of 8.7. Maximum numbers of excellent to good water quality have been found from Moist Deciduous Sal forest and Dry Peninsular Sal forest.

Keywords: forested catchment, forest types, water quality index

Introduction
The availability and quality of water in many regions of the world are threatened by overuse, misuse and pollution, and both are strongly influenced by forests. Many studies suggest that evaporation in very wet and very dry forests is likely to be greater from forests than from land covered with other sorts of vegetation, leading to a decrease in water from forested catchments as compared with. Indeed, the hydrological role of forests is complex and the precise impact on water supply varies between places and can also vary in one and the same place depending on such factors as the age and composition of the forest, soil types, climate, and management regimes. Moreover, different anthropogenic activities lead to a negative impact on the river water quality. Particularly problematic for drinking water abstraction are high TDS and ion content in some region. In Jharkhand, forest hydrology research in the different watershed situated in different forest types was conducted. The prevailing part of the studies performed for the stream Morwai in Northern Dry Mixed Deciduous Forest, Doomar in Dry Peninsular Sal Forest and Kentora in Moist peninsular Sal Forest.

Water quality is much depending on the desired use of water; hence different uses require different criteria of water quality assessment as well as standard method for reporting and comparing result of water analysis (Babiker *et al*., 2007) [2]. Therefore, understanding of the chemical composition of water is essential for evaluating its suitability for different purposes. Further, it is possible to understand the change in quality due to water–rock interaction (weathering) or any type of anthropogenic influences (Todd, 1980) [6]. In the last few decades, due to rapid change in land use and increase in human population, there has been a tremendous pressure on the demand of fresh water (Singh *et al*., 2014; Chandra *et al*., 2014) [5, 3].

WQI is commonly used for the detection and evaluation of water pollution and may be defined as a reflection of composite influence of different quality parameters on the overall quality of water. 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, while biological indices are derived from the biological information. Here attempt has been made to calculate the water quality index of the study area based on hydro chemical data.

In the present work, attempts have been made to carry out comparative study of water quality of surface water resources in three major forest types in the state (as per Champion and Seths classification). WQI and thematic maps for the various water quality parameters were used to derive an outline of water quality in different Sal forests. The study provides baseline for water quality analysis on the basis of forest types, since the watershed selected for the concerning study are situated in forest area. It may also help in future water resource planning for the area and also will help to derive role of vegetation and geomorphology in water quality of the area.

Material and Methods

Description of the Study Area

Present study was conducted for surface water quality in three small watersheds; Morwai in Chippadohar forest range in PTR forest division under Northern Dry Mixed Deciduous Forest which is a tributary of North Koel river, Doomar in Barkagaon forest range in Hazaribagh West forest division under Dry Peninsular Sal Forest; a tributary of Sakri river and Kentora in Goilkera forest range in Chaibasa forest division under Moist Decidous Sal Forest; a tributary of south Koel river. The schematic distribution of the small watersheds is given on Figure 1 is developed using digital elevation model (DEM) for the selected river basin.

Sampling and Sample Preparation

Water samples were taken from three sites during pre-monsoon season in the year 2019. The measurement of Dissolved oxygen, pH and water temperature was recorded at sampling site. The water samples were stored in ice boxes and immediately transported to IEM Pundag, Ranchi for analysis of water quality following common protocols.

Sample Analysis

The analyzed water quality parameters were: temperature, pH, total dissolved solids (TDS), Total Suspended Solids (TSS), dissolved oxygen (DO), biological oxygen demand (BOD), and NO3- N, SO_4^{2-}, Electrical Conductivity (EC), Total hardness, Total alkalinity, Sulphates, Calcium and Magnesium and Iron. These parameters have been chosen, as mainly related to the natural conditions – watersheds and forest peculiarities. Correlation coefficient was derived to establish the relationship between two variables. Water Quality Index (WQI) of all the three forest types was calculated considering 14 parameters. These parameters include for the purpose of calculation of WQI for the study area, 14 water quality parameters have been selected. They are TDS, pH, TA, TH, Ca, Mg, EC, NO_3, Cl, Fe, SO_4^{2-}, F^-, DO and BOD. The water quality index was calculated using quality rating scale and accordingly assigning weight values to the selected parameters. The standards of the water quality parameter are governed as per BIS: 10500-2012 and central pollution control board (CPCB) standards and their respective weight used in the present work are highlighted in Table 1. Since these watersheds are situated in the forest area thus Class-A as well as Class-D category of surface water quality of CPCB has been considered for analysis.

Table 1: Assignment of Significant Weight to Water Quality parameters

Chemical Parameters	Standards (BIS)	Weight	Relative weight
pH	8.5	4	0.034
TDS	500	5	0.00057
EC	1000	4	0.00029
Flouride	1	5	0.286
Chloride	250	5	0.00114
Nitrate	45	5	0.049
Sulphate	200	5	0.00143
Calcium	75	3	0.0038
Magnesium	30	3	0.01
Total Hardness	300	2	0.00095
DO	5	2	0.0572
BOD	2	5	0.143

WQI Calculation

Calculation of WQI was carried out in this work by Horton's method. The WQI is calculated by using the expression given in equation.

WQI = qn Wn / Wn

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

Wn= Unit weight of nth water quality parameter.

Quality rating (qn)

The quality rating (qn) is calculated using the expression given in equation.

qn = [(Vn – Vid) / (Sn- Vid)] x100

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.

Unit weight

The unit weight (Wn) is calculated using the expression given in equation.

Wn = k / Sn

Where,

Sn = Standard permissible value of nth water quality parameter.

k = Constant of proportionality and it is calculated by using the expression given in Equation.

k = [1/(1/ Sn=1,2,..n)]

Results and Discussion

The physico-chemical parameters of the analyzed surface water samples of the three sites including statistical measures such as minimum, maximum, average values and standard deviation are given in Table 2. The maximum and minimum value of major parameters has been shown in the table 3. The important water quality parameters are presented in Table 3. The pH in Northern Dry Mixed Deciduous Forest ranges from slight acidic to alkaline (6.6-8.7). However it was found alkaline in two other forest types. The measured EC of the surface water in the study area varies from 44µS cm^{-1} in Dry Peninsular Sal and highest was 714µS cm^{-1} in Northern Dry Mixed Deciduous Forest. Concentration of TDS in the surface water of the study area ranged from 26 mg /L in Dry Peninsular Sal to 447 mg L^{-1} in Northern Dry Mixed Deciduous forest. Dissolved oxygen (DO) in surface water is due to the oxygen diffusion from the surrounding air because of the aeration of water that has tumbled over falls and rapids and as a waste product of photosynthesis. Its concentration in water depends on the water flow velocity. The lowest and highest concentrations for dissolved oxygen were observed 3.2 mgL-1 and 10 mgL-1 in Northern Dry mixed forest.

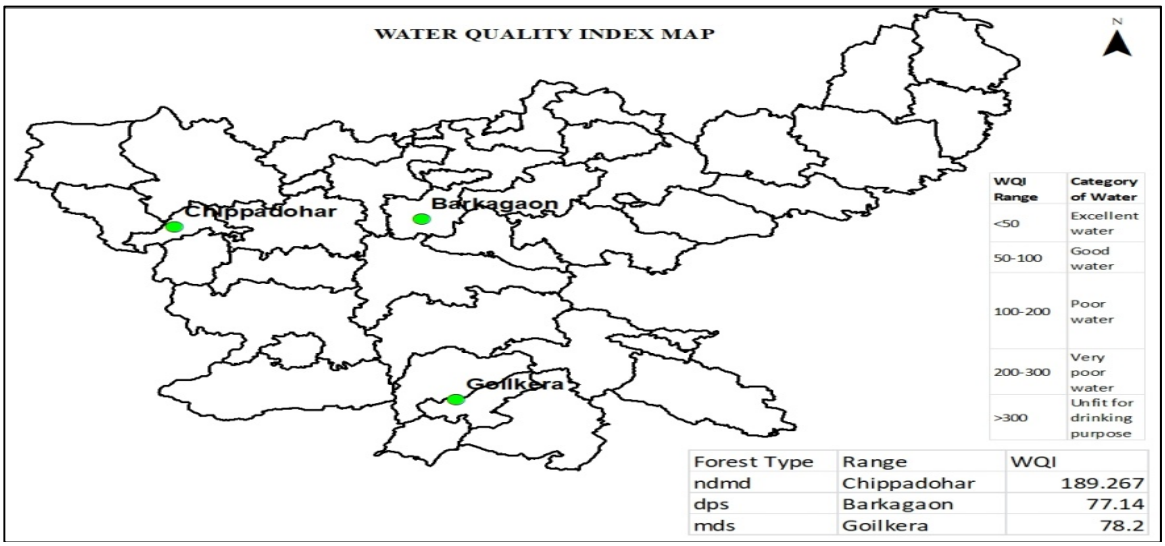
Table 2: Summary Statistics of Analytical Data

Forest Type	Parameters	Units	Minimum	Maximum	Mean	S.D.
NDMD	pH	-	6.6	8.7	7.96	0.856
	EC	µS/cm	102	714	230.84	425.35
	TDS	mg/L	122	447	224	124.97
	TH	mg/L	20	116	77.5	38.19
	Ca	mg/L	5.6	28	19.6	8.73
	Mg	mg/L	1.44	11.52	6.84	4.10
	TA	mg/L	63	136.5	99.48	33.01
	Cl	mg/L	4.86	79.65	18.45	29.98
	SO_4^{2-}	mg/L	6.52	77.6	17.74	29.05
	NO_3^-N	mg/L	2	14.9	5.02	4.93
	F^-	mg/L	0.08	0.77	0.291	0.26
	Fe	mg/L	0.43	1.96	0.79	0.61
	BOD	mg/L	1.1	3.7	2.02	0.091
	DO	mg/L	3.2	10	7.35	2.55
DPS	pH	-	7.2	8.7	8.03	0.49
	EC	µS/cm	44	350	110	99.4
	TDS	mg/L	26	196	65.1	54.7
	TH	mg/L	7.9	87	21	27
	Ca	mg/L	1.6	23.8	5.49	7.37
	Mg	mg/L	0.91	6.62	1.66	2
	TA	mg/L	8	92	24	28
	Cl	mg/L	6	42	13	12
	SO_4^{2-}	mg/L	0.4	39	14.56	16.81
	NO_3^-N	mg/L	0	4.3	1.7	1.8
	F^-	mg/L	0	0	0	0
	Fe	mg/L	0.04	1.76	0.5	0.58
	BOD	mg/L	0.1	4.2	1.57	1.34
	DO	mg/L	6.1	8.5	6.69	0.8
MDS	pH	-	7.1	8.1	7.7	0.4
	EC	µS/cm	137	256	174	48.7
	TDS	mg/L	78	154	104	30
	TH	mg/L	44	128	70	34
	Ca	mg/L	14	32	19	8
	Mg	mg/L	2.16	12.1	5.2	3.7
	TA	mg/L	62	136	87	29
	Cl	mg/L	4	12	7.8	2.1
	SO_4^{2-}	mg/L	4.64	17.6	8.93	3.87
	NO_3^-N	mg/L	1.4	2.8	2.1	0.4
	F^-	mg/L	0.68	0.8	0.7	0
	Fe	mg/L	0.1	0.4	0.2	0.1
	BOD	mg/L	0.4	4.7	1.83	1.39
	DO	mg/L	4.1	5.1	4.6	0.4

*NDMD- Northern Dry Mixed Deciduous *DPS- Dry Peninsular Sal *MDS- Moist Deciduous Sal, *EC- Electrical Conductivity, *TDS- Total Dissolved Solids, *TH-Total Hardness, *TA- Total Alkalinity

WQI of the Study Area - The water quality indexes (Ashwani *et al.*, 2015) [1] of the different forest types have been computed. The water quality index of the Northern Dry Mixed Deciduous forest is 189.267, fall under WQI 100-200. This reveals that the water quality is quite poor in Pre-monsoon season. This might be due to the low water availability and geographical conditions of the region. Because low water flow and water availability directly affects the major ion concentrations in the water body. The Water quality index of Dry Peninsular Sal forest is 77.14 and Moist Deciduous Sal forest is 78.2; this shows good water quality in the study area. The WQI values of the pre-monsoon samples are summarized in Table 3. One sample from Northern Dry Mixed Deciduous Forest is found unfit for drinking and one

sample from the same forest is also found very poor quality. Whereas Maximum number of Excellent water quality is found from Moist Deciduous Sal forest and Dry Peninsular Sal forest during pre-monsoon season.



Map 1: WQI of Pre-Monsoon Sampling of three Forest Types

Table 3: Pre- Monsoon Water Quality Index of Collected Water Samples

Forest Type	Sample Code	WQI	Description
NDMD	mor1	108.1189	Poor
	mor2	118.7269	Poor
	mor3	138.4849	Poor
	mor4	287.2112	Very Poor
	mor5	177.1451	Poor
	mor6	127.9862	Poor
	mor7	434.7438	Unfit for drinking
	mor8	110.8182	Poor
DPS	D 1	27.21704	Excellent
	D2	48.89887	Excellent
	D3	271.409	Very Poor
	D 4	25.15849	Excellent
	D 5	118.0631	Poor
	D6	152.5226	Poor
	D7	159.2563	Poor
MDS	G1	62.84726	Excellent
	G2	57.79149	Excellent
	G3	41.0621	Excellent
	G4	43.96343	Excellent
	G5	111.4893	Good
	G6	96.57079	Good
	G7	114.7967	Poor
	G8	96.82955	Good

Conclusion

The results suggest that the chemical composition of the surface water of all the three watersheds selected for the study in three different forest types is largely controlled by rock weathering with minor contributions from agriculture and anthropogenic sources. In majority of the samples, the analyzed parameters are well within the desirable limits and water is potable for drinking purposes. However, concentration of Total alkalinity exceeded the desirable limit at few sites. The WQI shows that 30% of surface water samples were found as excellent to good categories and can be used for direct consumption, while 47% water samples are of poor to very poor category and only one sample was found under unfit for drinking purposes. The water which is not suitable for direct consumption requires treatment before its utilization.

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