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EVALUTION OF WATER QUALITY INDEX (WQI) OF POND WATER OF PARADEEP AREA, ODISHA, INDIA

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ABSTRACT

Water quality index (WQI) is one of the reliable tools to examine overall water quality status. It also helps in prescribing the appropriate treatment technique as it reflects the composite influence of different water quality parameters. The present article evaluates the Water Quality Index of Paradeep area, Jagatsingpur district through surface water samples of four different locations in four different seasons of the year. The water quality was characterized through various physico-chemical parameters such as pH, Total hardness, Alkalinity (M), Turbidity, Total dissolved solids (TDS), Dissolved Oxygen (DO), Biological Oxygen demand (BOD), Fluoride, Chloride, Phosphate, Sodium, Potassium, Iron and Zinc. The WQI value of PW4 (472.195) was maximum while of PW1 was minimum (45.256). The results of the present investigation showed that pond water quality of PW1 and PW2 is good while PW3 and PW4 in study area are unfit for drinking purposes, and therefore, suitable treatment is highly essential.

Key Words: WQI, Pollution, Drinking water, Paradeep area.

INTRODUCTION

Water is a very precious resource and second to oxygen as being essential for existence of life. People can survive days, weeks as even longer without food but only about four days without water. Earth is also called as "blue planet" (Panda et al. 2016). Although 71% of Earth's surface is covered with water, but only 0.003% of the Earth's total volume of water is available for us as freshwater. Such a resource has remained the same in the last 2000 years whereas our population has increased fifty folds. This is the reason for water becoming scarce (Jhansilakshmi1 et al. 2014).Water resources are declining day by day at a faster rate due to rapid urbanization and population load. The deterioration of the water quality is now a global problem (Mahananda et al. 2010). From ancient times the rain water is being stored in small water body like ponds in most of the area in India. This water body work as water reservoir for various purposes throughout the year (Arya et al. 2011). Rapid growth of urban areas directly or indirectly affected existence of the ponds such as over exploitation of resources and improper waste disposal practice (Mishra et al. 2014). However, the quality of pond water has deteriorated due to discharge of wastewater from domestic pipelines, use of detergents, animal bathing, idol immersion, aquaculture etc. This deterioration has not only adversely affected the health of the surrounding people but also ruptured the aquatic life and fishing. Several physicochemical and biological factors may impart stress on fish growth and reproduction (Iwama et al. 2000). The water quality, hydrology and habitat conditions reflect impact of the urban drainage of the receiving water body (Sonneman et al. 2001). Anthropogenic activity on pond ultimately, deteriorate the water quality, accumulation of toxic chemical and sediment, shrinkage of catchment area leads to loss of aesthetic value(Chaurashiya et al. 2007).The pond water is mainly affected due to pilgrims and ritual activities by the people living in the nearby areas(Gupta et al. 2011). In India, man-made ponds have been used as an alternate source of drinking water and employed for washing of clothes and bathing purposes by washer men and local people (Mishra et al. 2014). The physico-chemical parameters have important significance in determining the trophic status of aquatic habitats (Sharma et al. 2009). The accumulation of various kinds of pollutants and nutrients through the domestic sewage, municipal effluents, and agricultural runoff in to the ponds leads changes in the physico-chemical characteristics of the freshwater.

MATERIALS AND METHODS

STUDY AREA

Paradeep is a seaport town of Odisha, India with a population of around 150,000. It is located at a distance of 98km from Cuttack and 120km from state capital Bhubaneswar. It lies on the Eastern most part of the state having 20degree 18' 59.5836ºNorth Latitude and 86 degree 36' 40.9176º East Longitude.

Paradeep area is adjoined by water bodies in three directions namely in the North, South and East. Bay of Bengal is on the South Eastern direction whereas Mahanadi river flows on the Northern side and drains from west to east. Fertilizer plants of Paradeep are a major chemical fertilizer producer in India and also polluting the peripheral environment. The effluents from Paradeep Phosphate Ltd. (PPL), Indian Farmers and Fertilisers Cooperative (IFFCO) Ltd., IOCL Refinery, East Coast Breweries, Goa Carbon Ltd., sewage from PPL Township and Paradeep Port Trust (PPT) Township are discharged into Atharabanki River which ultimately joins the Mahanadi River near the confluence point in the Bay of Bengal (Samantray et al. 2009). Due to the discharged effluents in the water bodies there is a chance of surface water and ground water pollution in this area.

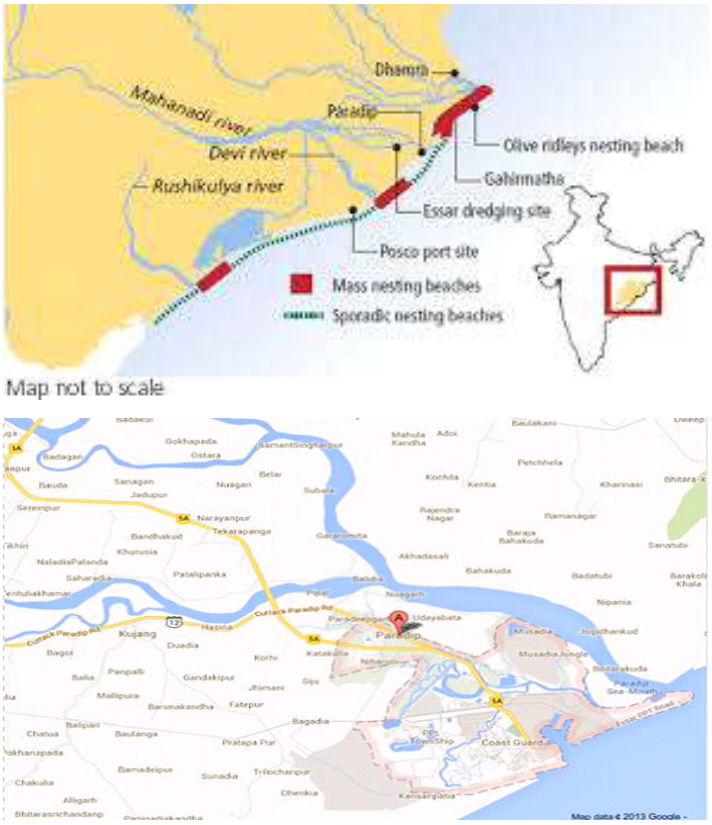

Fig. 1. Map showing study area

Pond water samples of four different locations of Paradeep area were collected spreading over a period of one year (Table1).

Table 1. Description of sampling locations

S. No.	Name of Location	Sampling number	Sampling source
1	Pond water at village SIJU	PW1	Village
2	Pond water near Carbon Factory	PW2	Goa Carbon Ltd
3	Pond water in between IOCL Refinery, Rangiagarh Village and New Railway station	PW3	Village Rangiagarh
4	Pond water in between Old Railway station, IFFCO Railway siding and BPCL marketing division	PW4	IFFCO Railway siding

Water samples collected from ponds were analysed as per standard procedure of APHA (1992). For calculating the water Quality Index (WQI), method described by Tyagi et al. (2013) has been employed. In this method the quality rating scale has been assigned to the parameters which are also weighed according to its relative importance in the overall water quality. The maximum weight of 4 has been assigned to the parameters like pH and TDS owing to their major importance in water quality assessment (Table 2). The weight of Alkalinity, BOD, Chloride and Zinc is 3 whereas of Total Hardness, Turbidity, Fluoride, Phosphate and Iron is 2. Other parameters like Sodium and Potassium are assigned the minimum weight of 1 as they play fewer roles in the water quality assessment and compared with the Indian Standard (BIS 1991).

Weighted Arithmetic Water Quality Index Method for calculation

The classification of water quality was made by adopting the Weighted arithmetic water quality index method using the common water quality variables. This method is mostly used by the scientific fraternity to standardise the water quality and the calculation of WQI was made by using the following equation:

$$WQI = \Sigma Q_i W_i / \Sigma W_i$$

The relative weight (W_i) of each parameter is calculated by using the weight of individual parameter (w_i) using the following mathematical relation;

$$W_i = (w_i)^t / \Sigma\ (w_i)^t \text{ as } \Sigma W_i = 1$$

Table 2. Water Quality parameters used in the present study

Sl. No	Parameters	Indian Standard values	Weight (w_i)	Relative Weight (w_i)
1	pH	6.5-8.5	4	0.118
2	Total hardness	300-600	2	0.059
3	Alkalinity	200-600	3	0.088
4	Turbidity	5-10	2	0.059
5	TDS	500-2000	4	0.118
6	DO	6	2	0.059
7	BOD	3	3	0.088
8	Fluoride	1.0-1.5	2	0.059
9	Chloride	250-1000	3	0.088
10	Phosphate	5	2	0.059
11	Sodium	20*	1	0.029
12	Potassium	10*	1	0.029
13	Iron	0.3-1.0	2	0.059
14	Zinc	5.0-15.0	3	0.088
			Σwi =34	ΣWi=1

Sub index (SI) is the first finding for each parameters i.e. $(SI)_i = QiWi$ where Qi = Quality rating scale

The relation between sub index and water quality index can be presented as

$$WQI = \Sigma (SI)_i / \Sigma Wi$$

$$WQI = \Sigma QiWi \quad \text{as } \Sigma Wi = 1$$

The WQI for all the parameters for all the sampling locations are calculated using the above mathematical equation and they are classified as per the following water quality rating (Table 3).

Table 3. Standard Values for Water Quality Rating

WQI level	Water Quality Rating
0-25	Excellent
26-60	Good
61-75	Poor
76-100	Very Poor
> 100	Unfit for Drinking Purposes

The WQI for sample PW1, PW2, PW3 and PW4 have been calculated using above formula and are given in the Table 4 A-E.

Table 4A. WQI for Sample PW1

S. No	Parameters	Values of water sample	Quality rating (Qi)	Relative Weight (Wi)	Sub-Index WiQi
1	pH	7.23	36.5	0.118	4.307
2	Total hardness	43	14.33	0.059	0.845
3	Alkalinity	112	56	0.088	4.928
4	Turbidity	13.4	37.31	0.059	2.201
5	TDS	212.8	42.56	0.118	5.022
6	DO	5.2	97.92	0.059	5.777
7	BOD	1.1	36.67	0.088	3.227
8	Fluoride	0.2	20	0.059	1.18
9	Chloride	74	29.6	0.088	2.605
10	Phosphate	5.1	102	0.059	6.018
11	Sodium	51.7	258.5	0.029	7.496
12	Potassium	1.8	18	0.029	0.522
13	Iron	0.051	17	0.059	1.003
14	Zinc	0.071	1.42	0.088	0.125
	WQI Values				**45.256**

Table 4B. WQI for Sample PW2

S. No	Parameters	Values of water sample	Quality rating (Qi)	Relative Weight (Wi)	Sub-Index WiQi
1	pH	8.1	80	0.118	9.44
2	Total hardness	88	29.33	0.059	1.73
3	Alkalinity	138	69	0.088	6.072
4	Turbidity	5.9	118	0.059	6.962
5	TDS	297.2	59.44	0.118	7.014
6	DO	5.8	91.67	0.059	5.408
7	BOD	0.9	30	0.088	2.64
8	Fluoride	0.13	13	0.059	0.767
9	Chloride	101	40.4	0.088	3.555
10	Phosphate	3.8	76	0.059	4.484
11	Sodium	71.6	358	0.029	10.382
12	Potassium	0.9	9	0.029	0.261
13	Iron	0.0516	17.2	0.059	1.015
14	Zinc	0.0541	1.082	0.088	0.095
	WQI Values				**59.825**

Table 4C. WQI for Sample PW3

S. No	Parameters	Values of water sample	Quality rating (Qi)	Relative Weight (Wi)	Sub-Index WiQi
1	pH	7.36	43	0.118	5.074
2	Total hardness	380	126.67	0.059	7.473
3	Alkalinity	170	85	0.088	7.48
4	Turbidity	10.46	209.2	0.059	12.343
5	TDS	760	152	0.118	17.936
6	DO	6.7	82.29	0.059	4.855
7	BOD	1.48	49.33	0.088	4.341
8	Fluoride	0.9	90	0.059	5.31
9	Chloride	260	104	0.088	9.152
10	Phosphate	1.2	24	0.059	1.416
11	Sodium	154	770	0.029	22.33
12	Potassium	1.35	13.5	0.029	0.391
13	Iron	0.0442	14.73	0.059	0.869
14	Zinc	0.0446	0.892	0.088	0.078
	WQI Values				**99.048**

Table 4D. WQI for Sample PW4

S. No	Parameters	Values of water sample	Quality rating (Qi)	Relative Weight (Wi)	Sub-Index WiQi
1	pH	7.54	52	0.118	6.136
2	Total hardness	190	63.33	0.059	3.736
3	Alkalinity	146	73	0.088	6.424
4	Turbidity	14.6	292	0.059	17.228
5	TDS	1270	254	0.118	29.972
6	DO	6.0	89.58	0.059	5.285
7	BOD	1.4	46.66	0.088	4.107
8	Fluoride	0.17	17	0.059	1.003
9	Chloride	920	368	0.088	32.384
10	Phosphate	143	2860	0.059	168.74
11	Sodium	1276	6380	0.029	185.02
12	Potassium	39	390	0.029	11.31
13	Iron	0.0268	8.93	0.059	0.527
14	Zinc	0.0184	0.368	0.088	0.323
	WQI Values				**472.195**

Table 4 E. Comparative water quality index of all the sample stations

S. No	Parameters	OBSERVED VALUES			
		PW1	PW2	PW3	PW4
1	pH	7.23	8.1	7.36	7.54
2	Total hardness	43	88	380	190
3	Alkalinity	112	138	170	146
4	Turbidity	13.4	5.9	10.46	14.6
5	TDS	212.8	297.2	760	1270
6	DO	5.2	5.8	6.7	6.0
7	BOD	1.1	0.9	1.48	1.4
8	Fluoride	0.2	0.13	0.9	0.17
9	Chloride	74	101	260	920
10	Phosphate	5.1	3.8	1.2	143
11	Sodium	51.7	71.6	154	1276
12	Potassium	1.8	0.9	1.35	39
13	Iron	0.051	0.0516	0.0442	0.0268
14	Zinc	0.071	0.0541	0.0446	0.0184
	WQI Values	**45.256**	**59.825**	**99.048**	**472.195**

* All parameters are reported in mg/L except pH

RESULTS AND DISCUSSION

The pH value of drinking water is an important index of acidity or alkalinity. A number of minerals and organic matter interact with one another to give the resultant pH value of the sample. In the present study, pH ranges from 7.23 - 8.1 and these are within the permissible limit in all samples. The water is alkaline in all cases (Table 4E).

Total Hardness is an important parameter of water quality whether it is to be used for domestic, industrial or agricultural purposes and here it ranges from 43-380 mg/L (Table 4E). Its highest value for PW3 (380 mg/L) indicates slight contamination in terms of Total hardness.

Alkalinity of water is defined as the ionic concentration, which can neutralize the hydrogen ions. It is the concentration of soluble alkalis in a solution. In the study, alkalinity ranged from112-170 mg/L which is less than the permissible limit in all samples (Table 4E).

Turbidity is a measure of the cloudiness or murkiness of water due to suspended particles and varied from 5.9 to 14.6 NTU in the study (Table 4E). PW4 sample has highest turbidity which is beyond the permissible limit. This reflects the presence of unwanted suspended particles due to continual disturbance of water source. PW1 is also coming under severe category whereas the PW3 falls under moderate level of contamination.

The level of TDS is one of the characteristics, which decides the quality of drinking water. In water, total dissolved solids are composed mainly of carbonates, bicarbonates, chlorides, phosphates and nitrates of calcium, magnesium, sodium, potassium and manganese, organic matter, salt and other particles. In the present study, TDS ranged from 212.8 - 1270 mg/L being maximum for PW4 which refers to moderate level in quality rating and minimum for PW1 (Table 4E).

DO is one of the important parameters in water quality assessment. Dissolved oxygen analysis measures the amount of gaseous oxygen (O_2) dissolved in an aqueous solution or level of free, non-compound oxygen present in water. Oxygen gets into water by diffusion from the surrounding air, by aeration (rapid movement) and as a by product of photosynthesis. In our study DO ranged from 5.2-6.7 mg/L, being >6.0 mg/L for PW3 whereas 6 mg/L for PW4 (Table 4E).

The amount of oxygen consumption by microorganisms during decomposition of organic matter is expressed by Biochemical Oxygen Demand (BOD). It ranged from 0.9 - 1.48 mg/L, being maximum for PW3 and minimum for PW2 (Table 4E).

In our study area role of fluoride in water quality is expected to be significant as it can be released to the environment during the production of phosphate fertilizers (which contain an average of 3.8% fluorine), bricks, tiles and ceramics. The fluoride content ranged from 0.17 -0.9 mg/L and found to be within permissible limit (Table 4E).

The chloride concentration serves as an indicator of sewage pollution. Soil porosity and permeability also has a key role in building up the chloride concentration. High chloride

content in water bodies harms agricultural crops, metallic pipes and injurious to people suffering due to heart and kidney diseases. In our study it ranged from 74 – 920 mg/L being maximum for PW4 which comes under sever chloride contamination (Table 4E).

The presence of phosphates in surface water may be through domestic sewage, detergents and agricultural runoff. The high level of both phosphates and nitrates can lead to eutrophication, which increases algal growth. In our study it ranged from 1.2 - 143 mg/L (Table 4E). The highest value was found for PW4 and lowest for PW3. The water sample of PW4 was severely poor quality in terms of phosphate.

Sodium is a vital cation in water in every respect. Apart from other sources, Industrial waste is a major contributor of sodium in water. From health point of view about 50% of body sodium is present in the bone, 40% in the extra-cellular fluid and the remaining 10% in the soft tissues. It is equally important in the extra-cellular fluid for specific function such as influencing cardiac muscle activities. In our study it ranged from 51.7 – 1276 mg/L (Table 4E). The highest value was found in PW4 and lowest in PW1. In no water sample the sodium content was under permissible level of water quality. In case of PW4 the level of sodium was alarmingly high reflecting a negative contribution towards quality of water. PW3 sample can also be termed as severely poor quality whereas PW2 comes under slightly poor quality.

The disposal of wastewater increases potassium level in water though weathering of rocks also contributes in the natural freshwater. In our study it ranged from 0.9 - 39.0 mg/L being maximum in PW4 and minimum in PW2. The excess of potassium makes PW4 slightly poor (Table 4E).

Iron was in excess in all the samples as it ranged from 0.0268 - 0.0516 mg/L (Table 4E). This may be attributed to industrial wastes and domestic discharges. The highest value was recorded for PW2 and lowest in case PW4 (Table 4E).

Zinc is an essential and beneficial element for human growth. Zinc most commonly enters the domestic water supply from deterioration of galvanized iron and dezincification of brass. In such cases lead and cadmium also may be present because they are impurities of the zinc used in galvanising. Zinc in water also may result from industrial waste pollution. Its range (0.0184 - 0.071 mg/L) in different samples indicates deterioration of water quality (Table 4E).The highest value was found in case of PW2 and lowest in case PW4.

The WQI values for the four sample site presented in the Tables (4A-E) clearly indicate declining of water quality as we moved from PW1 to PW4. The PWI which is a village site and is exposed to normal human activities; the water qualities come under GOOD category.

The 2nd site (PW2) near carbon factory also comes under GOOD but that is a border line case between POOR and GOOD with a WQI value of 59.825. The effluent as well as by the post work cleanliness activities of employee may be contributing to the declining process. The rise in parameters like pH , TDS, alkalinity , chloride total hardness compared to PW1 are the major contributors.

PW3 is located in between IOCL Refinery, Rangiagarh Village and New Railway station which makes it more prone to various human activities contributing to diminishing water quality since parameters like Total hardness, Alkalinity, TDS, DO, BOD, Fluoride, Chloride and Sodium had quite higher values which in some cases even exceed the normal values.

The WQI value 472.195 of PW4 water sample reflects the poorest quality of water which is not at all fit for human activities. Pond water (PW4) is in between Old Railway station, IFFCO Railway siding and BPCL marketing division. The location itself explains the poor quality. The normal activities in all those areas generate waste having such composition that plays a major role in altering the vital parameters of water. The parameters like TDS, chloride, phosphate, potassium and Sodium are alarmingly high in this sample leading to high value of WQI.

CONCLUSION

WQI values of the sampling points of Paradeep area reflect alarming water quality status and therefore, proper treatment is essential before using it for various purposes mainly drinking purpose. Activated carbon filtration, distillation, ion - exchange, reverse osmosis, UV radiation etc., are some techniques to improve quality of water.

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