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# Study of physico-chemical parameters and determination of water quality index of surface water resources in Talcher-Angul industrial complex, Odisha

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**ABSTRACT**

Water faces an endemic global shortage due to natural replenishment, melting of glaciers and receding in snowlines. This impact is visible as seventy rivers have stopped flowing into the sea; aquifers are depleting and the world's thirst for water is likely to become one of the most pressing issues of the 21st century. Rapid pace of industrialization, concurrent growth of urbanization, and change of life style of ever expanding population have the potential to damage the environment and degrade the quality of water resources. Since there has been growing concern about pollution in Angul-Talcher area due to industrial, mining and other anthropogenic activities, Central Pollution Control Board and Ministry of Environment & Forests have identified this zone as one of the hot spots in respect of pollution hazards. The present study is an attempt to provide a qualitative and quantitative status indicating the suitability of water resources for drinking purpose. The study on seasonal variations of physico-chemical characteristics along with its water quality of surface water resources fluctuated from one season to other thus making the sources unfit for human consumption. Water Quality Index (WQI) values for surface water in different seasons has been calculated to classify the sources according to pollution level and suitability for drinking purposes.



## 1. Introduction

Talcher –Angul Industrial complex of Orissa is situated on the right bank of the river Brahmani at latitude 200 95 'N to 210 10 ' N and longitude 840 55' E to 850 28 'E ,139m above sea level (ASL), and 150 km away from Bhubaneswar, the state capital of Orissa[1] (fig-1) . This area is one of the largest coal belts of India. Taking the advantages of the location, vast coal deposits, water availability and the manpower, Mahanadi Coal Fields Ltd. (MCL) has developed a number of open cast and underground mines in this industrial complex. Besides, a good number of coal based Thermal Power Plants (Talcher Super Thermal Power Project , Kaniha, Talcher Thermal Power Station, Talcher, Captive Power Plant, Nalco, Angul), several heavy industries (National Aluminimum Company, Angul, Heavy Water Project, Vikrampur, Bhushan Steel and Strips Ltd, Jindal Power and Steel Ltd, Nava Bharat Ferroalloys, Monet Ispat Ltd, Rungta Ltd etc), Coal washeries and a large number of ancillary medium and small scale industrial Units have come up in the area in the last few years. All these mining and industrial activities have caused significant degradation of environmental quality and now this area is considered as one among 24 most polluted areas of India[2] .The inhabitants of this area depend on ground water and surface water for their day to day uses besides mining and industrial activities. The discharge of effluents (partly treated or untreated) from different industries and mines have led to depletion of water quality of water resources. Such an alteration in the water quality makes the life miserable by inducing a number of water borne diseases [3].

In the present work an attempt has been made to study the seasonal variations in the water quality of surface water resources and the water quality is monitored by studying the changes in the parameters like pH, Dissolved Oxygen, Turbidity, Total Alkalinity, Total Dissolved Solids, Total Hardness, Calcium, Magnesium, Chloride, Biochemical Oxygen Demand, Iron, Sulphate etc .

## 2. Materials and Methods

### 2.1 Sample Collection

Water samples from surface water have been monitored at five different stations. The choice of these stations have been mostly on the basis of major industries, Coal mines and important township which are expected to make significant contributions to the pollution load on water resources. The selected monitoring stations are mentioned in Table –I. Water samples were collected from the said monitoring stations in clear polythene bottles at low temperature (Putting ice in box i.e. 40c). pH and DO tests were carried out immediately at the spot. After collection, the samples were brought to the laboratory after addition of the appropriate preservatives whenever necessary.

### 2.2 Physico-chemical analysis

Procedures as laid down in (APHA-2005) [4,5] have been followed for the analysis of different parameters such as pH,

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Dissolved Oxygen (DO), Turbidity, Total Alkalinity, Total Dissolved Solids (TDS), Total Hardness (TH), Calcium ($Ca^{2+}$), Magnesium ($Mg^{2+}$), Chloride ($Cl^{-}$), Biochemical Oxygen Demand (BOD), Iron ($Fe^{2+}$)& Sulphate ($So_4^{2-}$) of the water samples. An average of three observations in a season with respect to each monitoring station and parameters have been determined and results were compared with the Indian standards (IS0:10500) [6] for portable water.

**Table 1. Area of Study**

| Sl No. | Sampling Spot | Major Contribution to Pollution/Remarks |
|---|---|---|
| 1. | Open Pond, I.T.I. Chhak | Urban Waste & Mining Wastes |
| 2. | Open Pond Bonda Village | Fly Ash and effluent water of smelter plant, NALCO |
| 3. | Open Pond, Kulad Village | -do- |
| 4. | Open Pond, Tulsipal Village | -do- |
| 5. | Open Pond, Raniguda village | Urban wastes/domestic wastes of Angul |

## 3. Water Quality Index (WQI)

Water quality index (WQI) is commonly used for the detection and evaluation of water pollution and may be defined as "a rating, reflecting the composite influence of different quality parameters on the overall quality of water". The indices are broadly characterized into two parts: the physico-chemical indices and the 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 and are calculated using the species composition of the sample, the diversity of species, their distribution pattern, the presence or absence of the indicator species or groups etc. [5Trivedy and Goel, 1984]. Here attempt has been made to calculate the water quality index of Talcher-Angul industrial complex on the basis of [7]Harkins (1974), [8]Lohani (1981) and subsequently modified by [9]Tiwari *et al.*, (1986) based on physico-chemical data. For the purpose of present investigation physico-chemical data of twelve water quality parameters have been selected. These twelve parameters are pH, Dissolved Oxygen, Turbidity, Total Alkalinity, Total Dissolved Solids, Hardness, Calcium, Magnesium, Chloride, Bio-chemical Oxygen Demand, Iron and Sulphate.

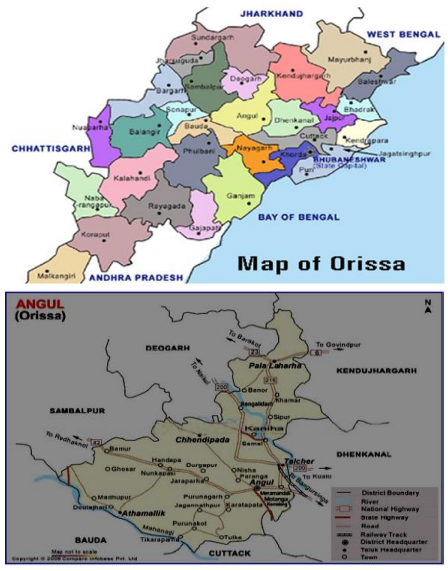


**Fig 1. Map of Orissa and map of Angul- Talcher Industrial complex.**

**Table 2. Drinking water standards and unit weights.**

| Sl.No | Water Quality Parameters | Standards | Recommending Agency | Unit Weight |
|---|---|---|---|---|
| 1 | pH | 7.0-8.5 | ICMR | 0.0354 |
| 2 | Dissolved Oxygen | 5.0 mg/l | EEC | 0.0496 |
| 3 | Turbidity | 10 NTU | ISI | 0.0248 |
| 4 | Total Alkalinity | 120 mg/l | USPHS | 0.0020 |
| 5 | Total Dissolved Solids | 500 mg/l | ICMR | 0.0004 |
| 6 | Total Hardness | 300 mg/l | ICMR | 0.0008 |
| 7 | Calcium | 75 mg/l | ICMR | 0.0033 |
| 8 | Magnesium | 50 mg/l | ICMR | 0.0049 |
| 9 | Chloride | 250 mg/l | ISI | 0.0009 |
| 10 | Biochemical Oxygen Demand | 5.0 mg/l | WHO | 0.0496 |
| 11 | Iron | 0.3 mg/l | ISI | 0.8276 |
| 12 | Sulphate | 200 mg/l | ICMR | 0.0012 |

**Table 3. Water Quality Index and their status.**

| Sl.No | WQI | STATUS |
|---|---|---|
| 1 | 0-25 | Excellent |
| 2 | 26-5 | Good |
| 3 | 51-75 | Poor |
| 4 | 76-100 | Very Poor |
| 5 | 100 and Above | Unsuitable for drinking |

## 4. Quality rating and weightage

In the formulation of water quality index, the importance of various parameters depends on the intended use of water; here water quality parameters are studied from the point of view of suitability for human consumption. The 'standards' (permissible values of various pollutants) for the drinking water, recommended by the Indian Council of Medical Research (ICMR) and unit weights are given in the above Table-2 .When the ICMR standards are not available, the standards of United States Public Health Services (USPHS), World Health Organization (WHO), Indian Standards Institution (ISI) and European Economic Community (EEC) have been quoted.

The quality rating $q_i$ for the $i^{th}$ water quality parameters (i = 1, 2, 3--12) was obtained from the relation

$$q_i = 100\ (v_i / S_i) \quad \text{"Equation 1".}$$

Where $v_i$ = value of the $i^{th}$ parameter at a given sampling station and $S_i$ = Standard permissible value of $i^{th}$ parameter. This equation ensures that $q_i = 0$ when a pollutant (the $i^{th}$ parameter) is absent in the water, while $q_i = 100$ if the value of this parameter is just equal to its permissible value for drinking water. Thus the larger the value of $q_i$ the more polluted is the water with the $i^{th}$ pollutant.

However, quality ratings for pH and DO require special handling. The range of pH for the drinking water is 7.0 to 8.5. Therefore, the quality rating for pH may be

$$q_{pH} = 100[(v_{pH} - 7.0)/ (8.5 - 7.0)] \quad \text{--"Eq.2".}$$

Where $v_{pH}$ = value of pH ~ 7, it means the numerical difference between $v_{pH}$ and 7.0, ignoring algebraic sign. Equation (2) ensures the $q_{pH} = 0$ for pH = 7.0.

In contrast to other pollutants, the case of DO is slightly complicated because the quality of water is enhanced if it contains more DO. Therefore, the quality rating $q_{DO}$ has been calculated from the relation

$$q_{DO} = 100[(14.6 - v_{DO})/(14.6 - 5)] \quad \text{-- -"Eq.3 ".}$$

Where $v_{DO}$ = value of DO.

In equation (3), 14.6 is the solubility of oxygen (mg/l) in distilled water at $0^{o}$C and 5.0 mg/l is the standard for drinking water. Equation (3) gives $q_{DO}$ = 0 when DO = 14.6 mg/l and $q_{DO}$ = 100 when $v_{DO}$ = 5.0 mg/l.

The more harmful a given pollutant is the smaller is its permissible value for drinking water. So the 'unit weights' for various water quality parameters are assumed to be inversely proportional to the recommended standards for the corresponding parameters i.e.

$$W_i = \frac{k}{S_i}$$ - -- "Eq.4".

Where $W_i$ = unit weight for the $i_{th}$ parameter (i = 1, 2, 3 ---- 12),

k = constant of proportionality which is determined from the condition and k =1 for shake of simplicity**.**

$$\sum_{i=1}^{12} W_i = 1$$ -----"Eq.5".

The unit weights $W_i$ calculated from equation (4) and (5) are listed in table 2.

**5. Calculation of WQI**

To calculate the Water Quality Index, first the sub index $(SI)_i$ corresponding the $i^{th}$ parameter is calculated. These are given by the product of the quality rating $q_i$ and the unit weight $W_i$ of the $i^{th}$ parameter i.e

$$(SI)_i = q_i \; x \; W_i$$ --------"Eq.6".

The overall Water Quality Index was then calculated by aggregating these sub indices (SI) linearly. Thus Water Quality Index could be written as

$$WQI = [\sum_{i=1}^{12} q_i W_i / \sum_{i=1}^{12} W_i]$$ **-----"Eq.**7".

This gives

$$WQI = \sum_{i=1}^{12} q_i W_i$$ ----"Eq.8a".

**since**

$$\sum W_i = 1$$ **--"Eq.**8b**".**

By using these formulas we have developed a program in Turbo C++ which has been given below**.**

**Table 4.1 Analyzed Physico-chemical parameters of Surface water of Open pond,I.T.I.CHHAK.**

| Sl. No | Parameters | 2013-14 | | |
|---|---|---|---|---|
| | | Winter | Summer | Rainy |
| 1 | pH | 7.8 | 8.6 | 7.9 |
| 2 | DO | 7.2 | 6.9 | 7.4 |
| 3 | Turbidity | 21 | 18 | 31 |
| 4 | Total Alkalinity | 166 | 99 | 104 |
| 5 | TDS | 190 | 212 | 199 |
| 6 | BOD | 4.8 | 6.2 | 6.4 |
| 7 | Calcium Hardness | 56 | 68 | 93 |
| 8 | Magnesium Hardness | 35 | 20 | 30 |
| 9 | Total Hardness | 91 | 88 | 123 |
| 10 | Chloride( $Cl^{-}$) | 14.5 | 20.4 | 15.3 |
| 11 | Iron | 1.50 | 0.90 | 1.40 |
| 12 | Sulphate($So_4^{2-}$) | 7.2 | 7.7 | 6.2 |

**Table 4.2. Analyzed Physico-chemical parameters of Surface water of Open pond ,Bonda village.**

| Sl. No | Parameters | 2013-14 | | |
|---|---|---|---|---|
| | | Winter | Summer | Rainy |
| 1 | pH | 7.8 | 8.5 | 8.3 |
| 2 | DO | 7.1 | 6.7 | 7.2 |
| 3 | Turbidity | 20.1 | 17.3 | 29.8 |
| 4 | Total Alkalinity | 165 | 94 | 101 |
| 5 | TDS | 201 | 228 | 193 |
| 6 | BOD | 4.9 | 6.3 | 6.6 |
| 7 | Calcium Hardness | 80 | 72 | 64.4 |
| 8 | Magnesium Hardness | 85 | 92 | 79 |
| 9 | Total Hardness | 165 | 164 | 143.4 |
| 10 | Chloride($Cl^{-}$) | 14.8 | 19.5 | 14.6 |
| 11 | Iron | 1.20 | 1.08 | 1.37 |
| 12 | Sulphate($So_4^{2-}$) | 5.8 | 7.0 | 5.1 |

**Table 4.3. Analyzed Physico-chemical parameters of Surface water of Open pond, Kulad village.**

| Sl. No | Parameters | 2013-14 | | |
|---|---|---|---|---|
| | | Winter | Summer | Rainy |
| 1 | pH | 7.8 | 8.4 | 7.9 |
| 2 | DO | 6.3 | 5.8 | 7.1 |
| 3 | Turbidity | 22 | 19 | 32 |
| 4 | Total Alkalinity | 163 | 98 | 103 |
| 5 | TDS | 197 | 214 | 200 |
| 6 | BOD | 4.9 | 6.3 | 6.4 |
| 7 | Calcium Hardness | 84 | 90 | 82 |
| 8 | Magnesium Hardness | 86 | 90 | 79 |
| 9 | Total Hardness | 170 | 180 | 161 |
| 10 | Chloride($Cl^{-}$) | 14.4 | 19.3 | 14.2 |
| 11 | Iron | 1.56 | 1.27 | 1.48 |
| 12 | Sulphate($So_4^{2-}$) | 6.9 | 7.5 | 6.1 |

**Table 4.4. Analyzed Physico-chemical parameters of Surface water of Open pond, Tulsipal village**

| Sl. No | Parameters | 2013-14 | | |
|---|---|---|---|---|
| | | Winter | Summer | Rainy |
| 1 | pH | 7.8 | 8.1 | 7.9 |
| 2 | DO | 7.3 | 6.9 | 7.45 |
| 3 | Turbidity | 24.2 | 20.7 | 36 |
| 4 | Total Alkalinity | 161 | 91 | 98 |
| 5 | TDS | 206 | 232 | 197 |
| 6 | BOD | 3.9 | 6.1 | 6.3 |
| 7 | Calcium Hardness | 76 | 67 | 61 |
| 8 | Magnesium Hardness | 82.4 | 91 | 77.5 |
| 9 | Total Hardness | 158.4 | 158 | 138.5 |
| 10 | Chloride($Cl^{-}$) | 14.5 | 19 | 14.1 |
| 11 | Iron | 1.21 | 1.10 | 1.58 |
| 12 | Sulphate($So_4^{2-}$) | 5.9 | 7.1 | 5.1 |

**Table 4.5. Analyzed Physico-chemical parameters of Surface water of Open pond, Raniguda village.**

| Sl. No | Parameters | 2013-14 | | |
|---|---|---|---|---|
| | | Winter | Summer | Rainy |
| 1 | pH | 8.0 | 8.4 | 8.1 |
| 2 | DO | 7.3 | 6.9 | 8.2 |
| 3 | Turbidity | 22 | 17 | 33.5 |
| 4 | Total Alkalinity | 109 | 153 | 104 |
| 5 | TDS | 192 | 205 | 186 |
| 6 | BOD | 5.0 | 6.4 | 8.3 |
| 7 | Calcium Hardness | 78 | 102 | 74 |
| 8 | Magnesium Hardness | 53 | 48 | 44 |
| 9 | Total Hardness | 131 | 150 | 118 |
| 10 | Chloride($Cl^{-}$) | 12.8 | 19.1 | 10.2 |
| 11 | Iron | 1.32 | 1.25 | 1.60 |
| 12 | Sulphate($So_4^{2-}$) | 12.8 | 10.8 | 8.8 |

**Table 5. Water quality index of surface water of various study areas of TALCHER-ANGUL industrial complex.**

| Sl.No | LOCATION | WQI OF THE YEAR 2013-14 | | |
|---|---|---|---|---|
| | | Winter | Summer | Rainy |
| 1 | Open Pond, I.T.I. Chhak | 431 | 268 | 408 |
| 2 | Open Pond Bonda Village | 349 | 318 | 401 |
| 3 | Open Pond, Kulad Village | 449 | 371 | 432 |
| 4 | Open Pond, Tulsipal Village | 351 | 323 | 459 |
| 5 | Open Pond, Raniguda village | 382 | 365 | 465 |

## 6. Results and Discussions

The WQI values within 0-25 are taken as excellent for domestic purposes. The WQI values within 26-50 are taken as good for domestic purposes and none of the sampling stations are coming under this category The WQI values within 51-75 are taken as poor quality for human consumption. Similarly WQI value 76-100 are taken as very poor for human consumption and WQI having value more than 100 has been taken as unsuitable for drinking and surface water of I.T.I. Chhak , Bonda , Kulad , Tulsipal and Raniguda villages are coming under this category .AS such Mining and Industrial activities needs attentions for water recourses to restrict the "fuel for pollution" pursued by industrialization induced eutrofication in Angul- Talcher industrial complex of Odisha.. Thus it is recommended for extensive studies so to aware every individual & industries and their participations for the sustainable development of water quality of water resources in Angul- Talcher industrial complex.

## 7. Conclusion

The present work provides a tool for seasonal and yearly variations of physico-chemical parameters of water resources of Angul-Talcher industrial complex which may be helpful in taking preventive measures and with alarming increase of surface water pollution, it becomes very much essential for the Orissa Government and Orissa Pollution Control Board (OPCB) to control further pollution of the surface water and deterioration in water quality. The overall management is necessary and Central Pollution Control Board (CPCB)/ State Pollution Control Board (SPCB) rules should be strictly implemented. Educating the urban as well as the rural mass is another major step to put a check on the surface water pollution.

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