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# Free Oxygen Budget of a Polluted Tropical River

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**Abstract**

Rivers are highly vulnerable water bodies to pollution due to their roles in assimilating or carrying off the municipal and industrial wastewater and run-off from agricultural land in their vast drainage basins. This paper analyzed the effluents discharged from industries contain chemicals which directly affect the parameters of the water. Present study deals with the investigation of monthly as well as seasonal variations of selected parameters in river Ami, which is a prime river in Gorakhpur, India. BOD 5 test measures the oxygen demand biodegradable pollutants whereas the COD tests measure the oxygen demand of oxidizable pollutants. These tests have its widest application in measuring waste loadings to treatment plants. The maximum value of BOD 5 was recorded to be 188 mg/l while COD was recorded to be 370 mg/l during summer and DO was completely absent during most part of the year.

**Keywords:** River Ami; Industrial effluent; DO; BOD; COD

## Introduction

River Ami a tributary of river Rapti originated from Sikhra tal near Hallur (Tehsil-Dumariyaganj) of Siddarthnagar district and passes through the border of two adjoining district Siddarthnagar and Basti [1,2]. Its rout also includes Sant Kabirnagar and Gorakhpur districts of Uttar Pradesh in India. It is one of the ancient rivers in India and initially the river was called Anoma [3]. During the course of 90 km it receives waste and effluent from many large and small industries, basically distilleries and paper industries [4]. One of the main reasons of pollution of surface water in our country is discharge of untreated sewage [5,6]. Sewage contain large amount of organic material that can be oxidized by microorganisms so it is called oxygen demanding waste. Due to degradation of organic compounds, leads to Oxygen depletion in the water bodies which effect or even kills aquatic life forms. The waste produced by industries like dairy, tannery, distillery, Oil refinery, textile, coal and synthetic rubber etc. are highly toxic. According to Valipour [7] depth of water level in drain below soil surface is introduced as the most effective parameter between all of the drainage parameters for drain discharge. Inorganic and synthetic organic pollutant caused several adverse effects on the life of the aquatic system [8,9].

Dissolved Oxygen (DO) is the amount of oxygen gas that is dissolved into water by any source. It is a measure of the degree of pollution by organic matter, the destruction of organic substances as well as the self-purification capacity of the water body [10]. Biochemical Oxygen Demand (BOD) is a measure of oxygen that would be needed by the microorganism to decompose the organic and inorganic pollutants in polluted water. Chemical Oxygen Demand (COD) is measure of oxygen consumed during the oxidation of the oxidizable organic matter by strong oxidizing agent. The BOD/COD ratio is a parameter of great importance for quantification of biodegradability of a contaminated effluent [11]. Standards are necessary for controlling the polluted water resources so that it would continue to be suitable for man and the aquatic system. Standard of different category of water has been prescribed by different health agencies [12]. Water quality standard of some agencies is given in Table 1.

Some studies in this direction have been done, but the studies are superficial because most of the studies show that many parameters have been considered at a time. Therefore, deep knowledge regarding important factors could not be highlighted and paucity exists. Therefore, this study has been designed to focus on the parameters related to oxygen content in water.

## Materials and Methods

River Ami in India was selected for this study on the ground of its historical, economic and its geography. For detail investigation of the river, five study sites (In four different districts) on the basis and varying intensity of industrial effluents discharged and the pollution load were located, as given in Table 1 and shown in the Figure 1. The study site at Lahurikhurd in district Siddarthnagar was marked as the control site, as no prominent source of pollution was present in the upstream of this study site. For true representation, the water samples were collected early in the morning from three points at each study site, first along the mid-stream followed by the point close to the two banks during June 2007 to May 2008. The analyzed water quality parameters include DO, BOD 5 and COD as prescribed by APHA [13]. Sampling was conducted fortnightly but for the ease of convenience, the average values are represented monthly and seasonally. The values had been subjected to statistical analysis also.

| Study Sites | Location | Source of Pollution |
|---|---|---|
| SS 1 | Lahurikhurd, Dist-Siddharthnagar | Marked as control site, no prominent source of pollution. |
| SS 2 | Rudhauli, Dist-Basti | Effluents from a sugar factory. |
| SS 3 | Maghar, Dist-Sant kabirnagar | Effluent from a paper industry. |
| SS 4 | Chhatai bridge, Dist-Gorakhpur. | Effluents from many small and large scale industries situated in GIDA (Gorakhpur Industrial Development Area). |
| SS 5 | Kauriram, Dist-Gorakhpur | This site was selected as a study site to evaluate the change in water quality incurred after traveling 21 Km. distance from the last source of pollution i.e., the study site 4. |

**Table 1:** Detail of the Study sites.

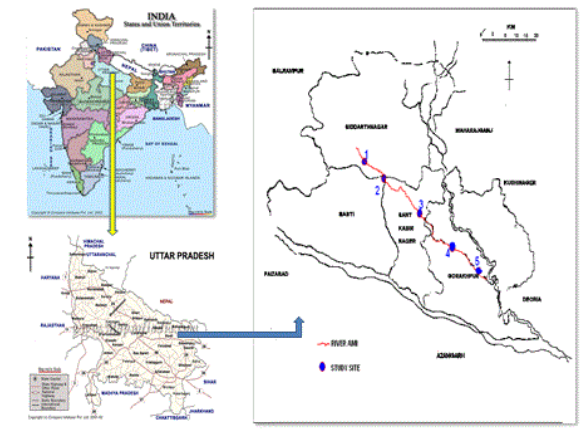


**Figure 1:** Map showing the route of River Ami.

## Results and Discussion

Monthly variation in DO of water in the river Ami is given in Table 2. Comparative study of the river water of all the sites show that maximum DO 6.8 mg/l was recorded during August at site 1 while most of the study sites show DO was completely absent during most part of the year. Seasonal variation of DO in the water of river Ami (Figure 2) show that the higher DO remains during rainy season followed by winter and the least DO was during summer season. The study of site-wise variation in DO show that the highest DO during most part of the study was at the study site 1. However, the DO was nil during several month in most of the sites which show negative correlation with all the parameters (Table 4).

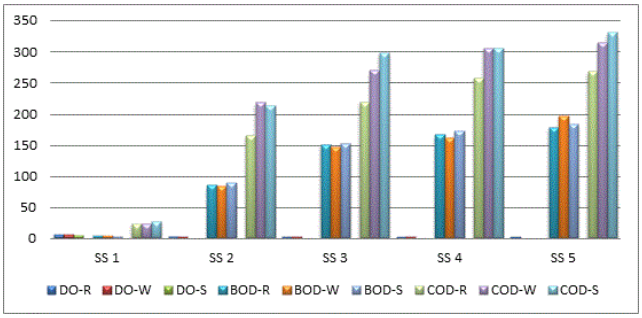


**Figure 2:** Seasonal variation of DO, BOD and C.

| Month | Temp | Site 1 | | | Site 2 | | | Site 3 | | | Site 4 | | | Site 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | DO | BOD5 | COD | DO | BOD5 | COD | DO | BOD5 | COD | DO | BOD5 | COD | DO | BOD5 | COD |
| June | 37.7 | 4.2 | 3.6 | 24 | 0 | 80 | 268 | 0 | 148 | 234 | 0 | 161 | 258 | 0 | 186 | 262 |
| July | 35.2 | 5.2 | 3.4 | 21 | 0 | 82 | 188 | 2.1 | 146 | 210 | 2.3 | 160 | 241 | 0 | 185 | 258 |
| Aug | 34.4 | 6.8 | 4.2 | 27 | 3.8 | 83 | 185 | 3.4 | 153 | 215 | 2.5 | 171 | 268 | 2.2 | 181 | 287 |
| Sept | 34.2 | 5.4 | 4.1 | 25 | 0 | 91 | 95 | 0 | 158 | 211 | 1.3 | 168 | 240 | 0 | 172 | 265 |
| Oct | 32.2 | 5.1 | 4 | 19 | 0 | 85 | 192 | 0 | 147 | 241 | 0 | 165 | 272 | 0 | 176 | 262 |
| Nov | 30.4 | 4.8 | 3.6 | 23 | 2.1 | 88 | 218 | 0 | 141 | 265 | 0 | 158 | 312 | 0 | 168 | 322 |
| Dec | 26.8 | 6.2 | 3 | 22 | 3.2 | 78 | 228 | 2.7 | 145 | 272 | 1.4 | 162 | 317 | 0 | 179 | 320 |
| Jan | 21 | 6.1 | 3.4 | 20 | 1.3 | 90 | 208 | 0 | 144 | 282 | 0 | 165 | 312 | 0 | 182 | 308 |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Feb | 23 | 5.3 | 3.8 | 29 | 0 | 79 | 217 | 0 | 157 | 262 | 0 | 164 | 282 | 0 | 180 | 312 |
| March | 23.5 | 5.4 | 3.2 | 30 | 0 | 86 | 262 | 0 | 155 | 312 | 0 | 178 | 251 | 0 | 174 | 330 |
| April | 24.4 | 5.7 | 3.1 | 28 | 0 | 98 | 285 | 0 | 152 | 320 | 0 | 176 | 355 | 0 | 185 | 370 |
| May | 40 | 4.6 | 3.3 | 26 | 0 | 92 | 278 | 0 | 156 | 326 | 0 | 174 | 368 | 0 | 188 | 360 |

**Table 2:** Monthly variation of DO, BOD5 and COD.

Physical process that affects DO concentrations is the relationship between water temperature and gas saturation. During the summer months in the warmer top portion of a water bodies, the total amount of oxygen present may be limited by temperature. The amount of oxygen that can be dissolved in water decreases, as the content of soluble salt increases. Also, the lower the temperature, the more will be the DO. The saturation level of DO is 14-15 mg/l at 0°C in fresh and clean water. With the rise in temperature value of DO reduces and reaches to 0 mg/l at 100C [14-16]. According to Rao [17] if the ratio of BOD and COD is 0.8 or higher, it indicate that the water is highly amenable to biochemical treatment, while the lower ratio indicate that the samples are not favorable to biological treatment. According to Ice and Sugden [18], DO concentrations are critical to aquatic communities and are an important measure of water quality condition in streams. In aquatic ecosystems except during active photosynthesis period in day, DO is usually a critical factor and at times it may cause anoxia (oxygen deficient) and death of aquatic organisms. In highly polluted systems the oxygen required for biochemical purposes exceed far more than the usual and rapid depletion in DO occurs [19,20].

Comparative study of all the sites shows that in the river Ami, the minimum BOD of water during December at site 1 and maximum BOD during May at site 5. Seasonally, BOD 5 was found to be highest during summer season followed by rainy and winter season at all the sites. Jain et al. and Bruce et al. [21,22] reported similar result. The statistical analysis of BOD5 and COD show positive correlation with all the parameters except DO. Monthly variation in BOD5 of water in the river Ami is given in Table 3. Among all the sites, the maximum value of BOD5 was recorded to be 188 mg/l at the site 5 during May 2008. The minimum BOD5 was 3.0 mg/l at site 1 during December 2007.

| Parameters | BIS | ISI | UPPCB | USPHS |
|---|---|---|---|---|
| DO (mg/l) | >5.0 | >5.0 | -- | >4.0 |
| BOD5 (mg/l) | <3.0 | 30 | 30 | -- |
| COD (mg/l) | <20.0 | <20 | 250 | -- |

**Table 3:** Standards of water quality. Standard of different category of water have been prescribed by different health agencies. BIS=Bureau of Indian Standard; ISI=International System of Units; UPPCB=Uttar Pradesh Pollution Control Board; USPHS=United State Public Health service.

Seasonal variation of BOD 5 in the water of river Ami (Figure 2) show that the higher BOD5 remains during summer followed by rainy and the least was during winter season. The study of site-wise variation in BOD 5 show that the highest BOD 5 during most part of the study was at the study site 5 followed by the study site 4, 3 and 2. However, the least value was recorded at the study site 1. BOD 5 shows positive correlation with all the parameters except the DO, which shows negative correlation at 0.01% level of significance (Table 4).

| | DO | BOD5 | COD |
|---|---|---|---|
| **DO** | +1.0000 | | |
| **BOD5** | -0.9275 | +1.0000 | |
| **COD** | -0.7906 | +0.9190 | +1.0000 |

**Table 4:** Correlation between DO, BOD and COD. P<0.001 (0.1% Level of significance for all values).

Higher BOD means more microorganisms, which in turn mean the presence of more organic waste. Due to heavy load of organic matter in water, it is bound to have a good growth of decomposer organisms on them, which would demand oxygen heavily for their respiration. This demand would exceed the oxygen production and re-aeration rate leading to DO deficiency and anaerobic conditions. High BOD levels indicates decline in DO because the oxygen that is available in the water is being consumed by the bacteria leading to the inability of fish and other aquatic organisms to survive in the river [23].

Monthly variation in COD of water in the river Ami is given in Table 2. Among all the sites the maximum COD was recorded to be 370 mg/l at the site 5 during April 2008. The minimum COD was 19 mg/l at site 1 during October 2007. The study of seasonal variation in COD (Figure 2) show that the highest COD was during summer season, followed by rainy and the least COD was during winter season. COD during most part of the study was at the study site 5 followed by the study site 4, 3 and 2. However, the least value was recorded at the study site 1. COD shows positive correlation with all the parameters except the DO, which shows negative correlation at 0.01% level of significance (Table 4).

The higher values of COD and lower values of DO in summer are influenced by various factors. Higher rainfall and river-flow cause the wash of organic matter into the surface water, which decreases the concentration of dissolved oxygen with biodegradation, while the increase in temperature causes a decrease in oxygen solubility, thus causing a further reduces the DO concentrations. In addition, as the amount of available DO decreases, undergoes anaerobic fermentation processes leading to formation of organic acids [24,25]. Jamil et al. [26] reported that a high ratio of DO (>0.5) indicates good biodegradability in the water while a ratio less than 0.3 is considered low, and corresponds to low biodegradability of the organic material present in the wastewater.

## Conclusion

From the result of study the levels of DO, BOD5 and COD were higher than WHO, CPCB etc. regulatory limits for discharged of

wastewater into river Ami. Therefore, the discharged of industrial and municipal waste would raise the level of these contaminants which make the river unsafe for usage for residence along the river for forming activities. DO show negative correlation with all the parameters, proving that the DO is inversely proportional to the parameters of pollution. Decreasing the value of DO and increasing the value of BOD 5 and COD indicate the higher concentration of organic compound in water. Reduction in value of BOD 5 and COD and increasing value DO during rainy season was due to addition of rain water. Based on the result obtained the wastewater should be monitor strictly by relevant agencies in order to prevent environmental pollution and reduced health hazards caused by activities of wastewater.

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