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# Assessment of Water Quality for the Gosikhurd Reservoir and Delineation of Mitigation Measures for Minimization of Pollution

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*Abstract:* **Major sources of water in nature are reservoirs, ponds, lakes and rivers. The quality of water in these sources keeps continuously changing due to the process of eutrophication and becomes a problem for sustenance of the water body. The study was conducted to know the water quality of Gosikhurd reservoir and contributing rivers to undertake requisite measures to protect quality of the water. The temperature of river water varied between 25.80C and 26.50C whereas for reservoir it was ranged from 260C to 26.80C. Dissolved oxygen (DO) content in the river and reservoir water ranged between 4.8-7.8 mg/L and 5.0-7.0 mg/L respectively. Impoundment of the river water does not have measurable adverse impact on DO, which seems to be adequate for fishing and other aquaculture activities. Turbidity of the river and reservoir water varies between 4.6-17.0 mg/L during non-monsoon season whereas during monsoon season it ranges between 230-260 mg/L and 65-190 mg/L for the river and reservoir respectively. The TDS of river and reservoir water ranges between 84 mg/L and 269 mg/L and 108 mg/L and 224 mg/L respectively. DO, BOD, COD, heavy metals, etc. were within permissible limits, and fall in 'C'&'D' classes, specified by CPCB. Comparable plankton diversities were observed in the water from reservoir as well as river. Palmer's Pollution Index (PPI) for phytoplankton varied from 3 to 5 whereas Shannon Wiener Diversity Index (SWI) for zooplankton ranged between from 2 and 2.86, which indicates low to moderate productivity of waters.**

*Keywords*: **DO, BOD, COD, Phytoplankton, Zooplankton, PPI, SWI**

## I. INTRODUCTION

In India a large number of rivers and reservoirs store the water for irrigation, fisheries, power generation and domestic purposes. The rivers and reservoirs play a crucial role in ecological restoration which ultimately helps in maintaining aquatic ecosystem and human welfare (Costanza et al., 1997). Rivers also help in assimilation and transport of various kinds of wastewaters, which act as principal sources of pollution (Singh et al., 2004; Vega et al., 1998). Rivers are very much susceptible to pollution; and hence, it becomes essential to control pollution and monitor the quality of water in catchment (Simeonov et al. 2003), and interpret variations in water quality (Dixon and Chiswell, 1996; Singh et al., 2004). Water resources are under threat due to potential pollution because of rapid industrial growth, rise in population, urbanization, intensive agriculture, and human interventions (Hutley, 1990; Agarwal et al., 2006; Singh et al., 2007). These activities hasten the sedimentation of reservoir due to siltation and deposition of organic load that triggers the eutrophication activity and ultimately deteriorate the habitat quality.

Healthy aquatic ecosystem depends on overall water quality and biological variability (Ramulu and Banergy, 2013). The physico-chemical characteristics is helpful in recognizing the level of pollution but variation in trophic conditions of water are observed in the biotic community-structure and also species types and their pattern, distribution and diversity (Kaushik and Saksena, 1995). We can understand biological phenomena in water only when we have water quality data on physico-chemical characteristics. Therefore, periodic water quality monitoring helps in knowing the limnochemical and limnobiological components of the ecosystem (Tiwari, 1992). The study was conducted to understand the spatio-temporal changes in quality of water in Gosikhurd reservoir and contributing rivers in order to know and identify the effects on water quality of contributing rivers and reservoir after the impoundment. The study will be useful to recognize the level of pollution in reservoir and to recommend required remedies to protect the quality of water for sustenance of the reservoir.

## II. MATERIALS AND METHODS

**Study area:** Gosikhurd dam is located on Wainganga river near Pauni in Bhandara district in Maharashtra state of India (Fig. 1). The dam comprises of thirty-three spillway gates in order to regulate e irrigation water into the river. The dam is having 22.5 m (74 ft.) height and 1,135 m (3,724 ft.) length. The volume of the dam is 3.83 million cubic meters (MCM) with gross water storage capacity is 1,146 MCM. The total irrigation potential covered in this project is of the order of 2,50,800 ha. Total catchment area of the Gosikhurd reservoir is 34,862 sq.km out of which 24,243 sq.km area lies in Madhya Pradesh and 10,619 sq.km in Maharashtra state.

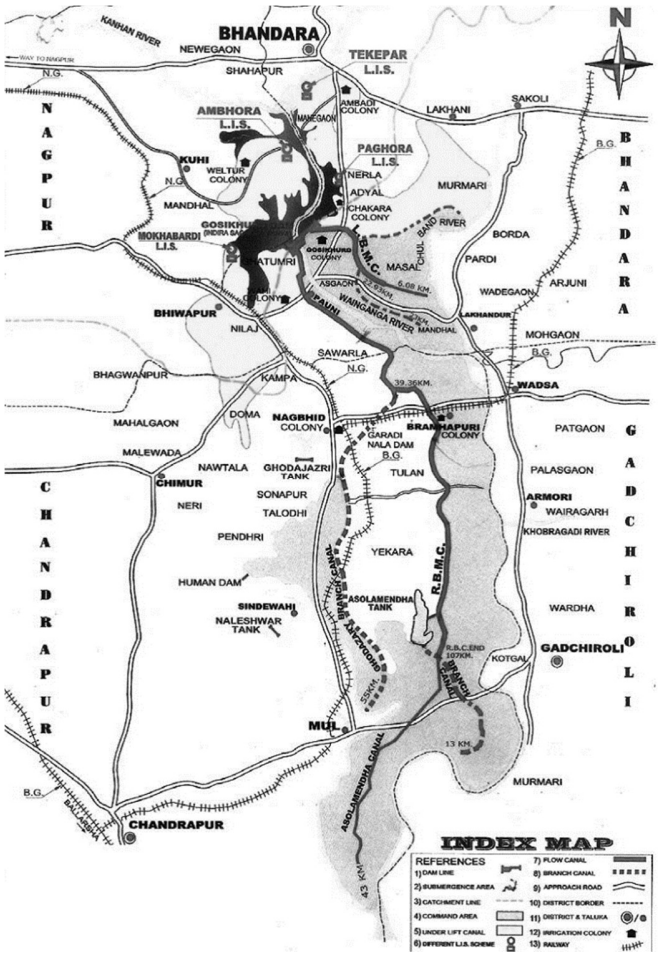


**Fig. 1. Location map of Study Area**

**Sampling and analysis:** The water sampling was done from different locations in Gosikhurd reservoir as well as from the Wainganga river during three seasons viz. pre-monsoon, monsoon and post-monsoon. Preservation and testing of the water samples for physicochemical, bacteriological, and biological parameters and heavy metals was done as per standard methods (APHA, 1998 & 2012).

## III. RESULTS AND DISCUSSION

### Water Quality during Pre-monsoon Season

Water quality is the characteristics of water which indicates its suitability for designated purpose Water quality is defined by physicochemical and biological parameters. The cause-effect relationship between water constituents and prevailing problems results in an evaluation of degree of acceptability of the water quality. The details of sampling locations for Gosikhurd reservoir are provided in Table 1. The results on physicochemical parameters, metals, bacteriological parameters and planktons are depicted in Tables 2 through 4.

### Water Quality: River

In the month of June, the flow of river is low and therefore, water in the Gosi khurd reservoir is in stagnant condition with almost uniform inflow and outflow rates of water.

River water samples were taken at a distance of about 200 m from the spillage gate and near Ambhora village at about 9 km upstream of reservoir. The river water showed pH of 6.6. Turbidity of water ranged between 10 and 17 NTU. Conductivity and TDS of water were 381 - 449 µS/cm; and 229 - 269 mg/L respectively. Alkalinity and Hardness of samples found between 140 - 170 mg/L, and 140 - 156 mg/L respectively. Calcium, magnesium, sodium and potassium content of samples were 26-27 mg/L; 18-21 mg/L; 46-70 mg/L; and 4.0-7.0 mg/L respectively. Chloride, sulphate, phosphate and nitrate content were 34-52 mg/L; 14-15 mg/L; 0.13-0.13 mg/L; and 2-5.0 mg/L respectively. Except manganese (0.16-0.12 mg/L), the heavy metals contents were below detection limits. Total coliforms (TC) were found in the range of 70-280 CFU/100 ml whereas Fecal coliforms (FC) were 50-70 CFU/100 ml. This shows that reservoir water is bacteriologically contaminated and hazardous for health. Phytoplankton density of the water sample ranges from 203906-360603 individuals/100, while zooplankton density ranges from 351-7536 individuals /$m^3$. The phytoplankton found to be higher than zooplankton in the water samples.

### Water Quality: Gosikhurd Reservoir (Surface)

The pH of surface water ranged between 6.9 and 7.3. The conductivity of water from surface and depth was found in the range of 364-449 µS/cm. Alkalinity and Hardness of surface water were ranged between 132-180 mg/L and 140-148 mg/L respectively. These parameters did not vary significantly in surface water of the reservoir. The respective content of sodium and potassium were 40-42 mg/L and 3-4 mg/L. Chloride, sulphate and phosphate were ranged between 24-38 mg/L; 8.0-87 mg/L; and 0.1-0.2 mg/L respectively. DO was found between 4.8 and 6.8 mg/L which might be due to photosynthesis activity of phytoplankton on the surface water of the reservoir. Except manganese (0.15-0.2 mg/L) other heavy metals were not detected. The respective TC and FC were ranged between 24-790 CFU/100ml ml and 1-170 CFU/100ml. Phytoplankton density ranged from 15318-525335

individuals/100 ml, while zooplankton density ranged from 179-3179 individuals/$m^3$.

**Water quality during monsoon season**

**Water Quality: River**

The river water pH was observed to be 7.3. Turbidity of water ranged between 230 and 260 NTU. Conductivity and TDS of water were found to be 141-176 µS/cm; 85-105.5 mg/L respectively. Alkalinity and hardness of water found between 92 and 96 mg/L and 78 and 80 mg/L respectively. Calcium, magnesium, sodium and potassium content of water were 17.6-20.8 mg/L; 6.7-8.6 mg/L; 11-12 mg/L; and 5.6-6.0 mg/L respectively. Chloride, sulphate, phosphate and nitrate content were 16-20 mg/L; 15-18.2 mg/L; 0.76-0.46 mg/L; and 1.41-3.51 mg/L respectively. Iron and manganese found to be more than BIS Limit with respective content of 2.04-1.26 mg/L and 0.14-0.15 mg/L, which might be due to decomposition of organic matter at the bottom of the reservoir, which has created reducing condition, under which insoluble iron and manganese at the bottom get solubilize. Other heavy metals were not found in any of water samples. TC and FC counts were 480-790 CFU/100 ml 38-49 CFU/100 ml respectively. Phytoplankton density of water sample ranges from 6780-9040 individuals/100 m, while zooplankton density ranges from 143-286 individuals/$m^3$.

**Water Quality: Gosikhurd Reservoir (Surface)**

The pH of surface water from the reservoir was found between 7.4 and 7.7. The conductivity of water was found in the range of 178-201 µS/cm. Alkalinity and Hardness of water ranged between 84-100mg/L and 80-100 mg/L respectively. Respective sodium and potassium contents were 9.7-11.8 mg/L and 2.4-5.4 mg/L. Chloride, sulphate and phosphate were ranged between 16-24 mg/L; 12-17.1 mg/L; and 0.1-0.4 mg/L respectively. DO was found between 5.4 -6.8 mg/L. Iron and Manganese content were found as 0.44-0.83 mg/L and 0.04-0.09l mg/L respectively. Other heavy metals were not detected in river water. The respective counts of TC and FC were observed as 40-400 CFU/100ml and 9-42 CFU/100ml. Phytoplankton density ranges from 502-8287 individuals/100 ml, while zooplankton density ranges from 36-893 individuals/$m^3$.

**Water Quality: Gosikhurd Reservoir (Depth)**

The pH of water was found between 7.2 and 7.3. The conductivity of water was found in the range of 183-196 µS/cm. Alkalinity and Hardness of water were ranged between 96-108 mg/L and 88-100 mg/L respectively. Sodium and potassium content were observed to be 12.1-12.8 mg/L and 3-4.8 mg/L respectively. Chloride, sulphate and phosphate were ranged between 22-24 mg/L; 13-15 mg/L; and 0.1-0.3mg/L respectively. DO was found between 5.0 and 6.1 mg/L. Iron and Manganese content were 0.58-0.86 mg/L and 0.11-0.16 mg/L respectively. Other heavy metals in water were below detection limits. TC and FC counts were found as 150-300 CFU/100ml and 60-98 CFU/100ml respectively. Phytoplankton density ranges from 753-1507 individuals /100ml, while zooplankton density ranges from 214-464 individuals/$m^3$.

**Water quality during post-monsoon season**

**Water Quality: River**

The pH of water ranged between 7.4 and 7.7. Turbidity of water ranged from 4.6-5.4 NTU. Conductivity and TDS were found to be 277-308 µS/cm; 166-185mg/L respectively. Alkalinity and hardness of water were found between 120 and 148 mg/L and 120-148 mg/L respectively. The respective content of calcium, magnesium, sodium and potassium in water was found to be 28.8-36.8 mg/L; 8.6-14.4 mg/L, 14.9-16.3 mg/L, and 2.6-2.8 mg/L. The chloride, sulphate, phosphate and nitrate in water ranged from 16.0-20.0 mg/L, 14.0-15.4 mg/L, 0.2 mg/L, and 00.4-0.7 mg/L respectively. DO in water was found to be 5.0 - 5.7 mg/L. Iron and manganese were observed in traces whereas other heavy metals were below detection limits. TC and FC counts were 10-36 CFU/100 ml 6-32 CFU/100 respectively. Phytoplankton density ranged between 100-167 individuals/100 ml whereas zooplankton density of water samples ranged from 10045-19587 individuals/$m^3$.

**Water Quality: Gosikhurd Reservoir (Surface)**

The pH of water was found between 6.9 and 7.3. The conductivity, alkalinity and hardness of water ranged between 213-224 µS/cm, 96-112 mg/L and 72-124 mg/L respectively. These parameters did not vary significantly in surface and bottom water samples of the reservoir. Sodium and potassium were observed to be 11.6-12.3 mg/L and 2.5-3.0 mg/L. Chloride, sulphate and phosphate were ranged between 12-18 mg/L; 11.3-12.4 mg/L; and 0.12-0.35 mg/L respectively. DO was found between 4.4 and 7.8 mg/L. High, values of DO were due to photosynthesis activity of phytoplankton on the surface water of the reservoir. Iron and manganese were found in traces whereas other heavy metals were below detection limits. TC and FC were ranged between 16-300 CFU/100ml and 6-210 CFU/100ml respectively. Phytoplankton and zooplankton density ranges from 2009-19587 individuals/100 ml and 0-2167 individuals/$m^3$ respectively.

**Water Quality: Gosikhurd Reservoir (Depth)**

The pH of depth water was found between 6.8 and 7.0. The conductivity of water was found in the range of 215-229 µS/cm. Alkalinity and hardness of water was ranged between 92-108 mg/L and 96-100 mg/L respectively. Sodium and potassium observed to be 11.5-12.1 mg/L and 2.6-2.8 mg/L respectively. Chloride, sulphate and phosphate were ranged between 12-16 mg/L;11.4–12.9 mg/L; and 0.20-0.49 mg/L respectively. DO of water varied from 5- 5.8 mg/L. The lower DO was observed due to the presence of oxygen demanding pollutants like organic matter, resulting in rapid depletion of DO. It might be because of utilization of oxygen for degradation of organic matter deposited at the bottom of reservoir. Iron and manganese content in depth water was ranged between 0.169 to 0.970 mg/L and 0.063 to 0.420 mg/L respectively. Iron and manganese content in depth water samples might be due reducing

conditions at the bottom, wherein insoluble iron and manganese at the bottom got solubilized. The TC and FC counts ranged between 16-330 CFU/100ml and 8-130 CFU/100ml respectively. Phytoplankton and zooplankton density of water ranged from 19336-55497 individuals/100 ml and 1700-5200 individuals /$m^3$respectively.

TABLE 1
Details of Sampling location for Gosikhurd Reservoir and Upstream

| Sr. No. | Location | | Latitude (N) | Longitude (E) |
|---|---|---|---|---|
| 1 | Upstream | Bhandara | $20^0$52'35.0" | $79^0$36'45.1" |
| 2 | | Ambhora | $20^0$52'30.3" | $79^0$36'30.4" |
| 3 | Reservoir water | | $20^0$52'29.9" | $79^0$36'13.9" |
| 4 | | | $20^0$52'40.9" | $79^0$36'19.1" |
| 5 | | | $20^0$52'44.6" | $79^0$36'19.1" |
| 6 | | | $20^0$52'45.1" | $79^0$36'37.8" |
| 7 | | | $20^0$52'45.1" | $79^0$36'37.8" |
| 8 | | | $20^0$52'45.1" | $79^0$36'37.8" |
| 9 | | | $20^0$52'45.1" | $79^0$36'37.8" |
| 10 | | | $20^0$52'45.1" | $79^0$36'37.8" |

The Gosikhurd reservoir water was observed to be polluted due to release of sewage and other pollutants from Nag river carrying sewage from Nagpur city. The contributing rivers also receiving various pollutants due to anthropogenic activities in in the catchment areas. Agricultural run-off might have also contributed towards degradation in water quality of contributing rivers and the reservoir. Chemicals, pesticides and fertilizers are commonly used to increase the agriculture yield, which ultimately find their way in water bodies. These chemicals get diluted in the rapid flowing rivers, however, there is a possibility of alarming concentrations of chemicals affecting water quality in years to come. Further, low concentrations of nitrogen, phosphorous and potassium were observed in the water samples.

## Water Quality Management Plan (WQMP)

Water quality management plan is prepared to reduce pollutants into urban run-off by reducing sources of pollutants by adapting appropriate management practices. Considering any variation in water quality parameters because of developmental activity in Gosikhurd reservoir and change in natural phenomenon, water quality monitoring at regular intervals is very much needed. Accordingly, a water quality management plan is suggested.

## Observations

Water quality evaluation was undertaken during the months of June, August and October 2018. The salient observations are given below.

- Temperature of upstream of Gosikhurd Reservoir ranged between 26-26$^0$C whereas temperature of Gosikhurd Reservoir was in the range of 26-26.6$^0$C.
- Remarkable variations were recorded in turbidity levels of the reservoir and river waters. Comparatively lower turbidity was observed in Gosikhurd Reservoir in both the seasons.
- Dissolved oxygen levels of upstream of Gosikhurd Reservoir were observed to be 5.6- 7.0 while for e Gosikhurd Reservoir it ranged from 4.8 to 6.8.
- Dissolved Oxygen levels are sufficient for sustaining fishery. Cold-water fish require minimum DO level 6 mg/L while tropical freshwater fish require minimum DO level 5 mg/L. In the present study, observed minimum DO level was above 4.8 that is alarming condition for aquatic system (flora & fauna).
- Heavy metals such as Fe and Mn were found predominantly in the water whereas other heavy metals were below detection limits.
- Phytoplankton and zooplankton indicates the impact of impounding on the flora and fauna.
- Phytoplankton density in water samples was found to be higher than zooplankton density.
- The water quality monitoring Gosikhurd reservoir should be undertaken once in a year preferably in post- monsoon for maintaining the water quality of reservoir.

## Recommendations

It is generally desirable to clear vegetation in the submergence area to avoid organic pollution due to vegetation and to minimize methane emission.

- The reservoir water is marginally to moderately suitable for irrigation. However, microbial contamination warns for careful irrigation practices with restricted crop selections.
- Appropriate water treatment followed by disinfection is very much essential for supplying the water for drinking purpose.
- Nagpur city sewage flowing through Nag River must be intercepted and subjected to treatment to minimize the pollution load in the reservoir. Appropriate treatment option needs to be worked out based on flow pattern and characterization of wastewater streams for recycle / reuse of treated sewage
- A comprehensive plan for treatment and post treatment monitoring to assess quality of water in reservoir must be prepared to ensure its sustenance both in terms of biological diversity and physico-chemical properties.

TABLE 2
Physicochemical characteristics of water from Gosikhurd reservoir and upstream

| S. N. | Parameters | Pre monsoon | | Monsoon | | Post monsoon | |
|---|---|---|---|---|---|---|---|
| | | Upstream water | Reservoir water | Upstream water | Reservoir water | Upstream water | Reservoir water |
| 1 | Temperature ($^0$C) | 26 - 26.5 | 26.1 - 26.5 | 26.1-26.2 | 26.0-26.5 | 25.8-26.0 | 26.0-26.8 |
| 2 | pH | 6.6 | 6.9 – 7.3 | 7.3 | 7.4-7.7 | 7.4-7.7 | 7.0-7.7 |
| 3 | Turbidity (NTU) | 10 - 17 | 8-10 | 230-260 | 65-190 | 4.6-5.4 | 3.5-19.0 |
| 4 | Conductivity (µS/cm) | 381-449 | 364-373 | 141-176 | 178-201 | 277-308 | 213-223 |
| 5 | TDS | 229-269 | 218-224 | 84-106 | 108-121 | 166-185 | 128-134 |
| 6 | Total Alkalinity as $CaCO_3$ | 140-170 | 132-180 | 92-96 | 84-100 | 120-148 | 96-112 |
| 7 | Total Hardness as $CaCO_3$ | 140-156 | 140-144 | 80 | 84-100 | 128-148 | 72-124 |
| 8 | Calcium as $Ca^{++}$ | 26-27 | 30-32 | 17.6-20.8 | 17.6-24 | 28.8-36.8 | 19.2-35.2 |
| 9 | Magnesium as$Mg^{++}$ | 18-21 | 14-16 | 6.7-8.6 | 5.8-10.6 | 11.5-13.4 | 8.6-14.4 |
| 10 | Sodium as $Na^+$ | 46-70 | 40-42 | 11-12 | 9.7-13.1 | 14.9-16.3 | 11.6-12.3 |
| 11 | Potassium as $K^+$ | 4-7 | 3-4 | 5.6-6 | 2.5-5.4 | 2.6-2.8 | 2.5-2.9 |
| 12 | Chloride as $Cl^-$ | 34-52 | 24-38 | 16-20 | 16-24 | 16-20 | 12-18 |
| 13 | Sulphate as $SO_4^{2-}$ | 14-15 | 8-10 | 14.9-18.3 | 12.0-17.1 | 14.0-15.4 | 9.7-16 |
| 14 | Phosphate as $PO_4^{3-}$ | 0.13 | 0.1-0.2 | 0.5-0.7 | 0.1-0.4 | 0.2 | 0.1-0.3 |
| 15 | Nitrate as $NO_3^-$ | 2-5 | 0.1-0.5 | 1.4-3.5 | 3.3-4.1 | 0.4-0.7 | 0.4-1.1 |
| 16 | Fluoride as $F^-$ | 0.3 | 0.3 | 0.2-0.7 | 0.2 | 0.2-0.3 | 0.1-0.2 |
| 17 | DO | 5.6-6.8 | 4.8-6.4 | 6.2-7.0 | 5.4-6.8 | 5.0-5.7 | 4.4-7.8 |
| 18 | SAR (meq/L) | 13.8-19.9 | 11.8-12.4 | 4.4-4.7 | 3.9-4.5 | 4.6-4.8 | 3.8-4.5 |
| 19 | ESP (meq/L) | 41.0-48.2 | 37.0-38.4 | 21.5-23.1 | 18.7-21.6 | 23.2-24.9 | 21.7-26.7 |
| 20 | RSC( meq/L) | 2.4-3.1 | 2.0-3.3 | 1.8-1.9 | 1.3-1.8 | 1.9-2.6 | 1.1-2.3 |
| 21 | TC (CFU/100 ml) | 70-280 | 204-790 | 480-790 | 40-400 | 10-36 | 16-300 |
| 22 | FC (CFU/100 ml) | 50-70 | 4-170 | 38-49 | 9-42 | 6-32 | 6-210 |

Note: Unit for parameters at Sr. Nos. 5-17 is mg/L

TABLE 3
Heavy Metal contents of Gosikhurd Reservoir and Upstream

| S N. | Parameter | Pre monsoon | | Monsoon | | Post monsoon | | *BIS Limit (ppm)* | *ICP-OES detection limit (ppm)* |
|---|---|---|---|---|---|---|---|---|---|
| | | Upstream water | Reservoir water | Upstream water | Reservoir water | Upstream water | Reservoir water | | |
| 1 | Cd | ND | ND | 0.01-0.02 | 0.0002 - 0.0007 | BDL | BDL | *0.003* | *0.0001* |
| 2 | Co | ND | ND | ND | ND | BDL | BDL | | |
| 3 | Cr | ND | ND | 0.01-0.02 | BDL | BDL | BDL -ND | *0.05* | *0.01* |
| 4 | Cu | ND | ND | 0.05-0. 01 | 0.002-0.004 | BDL | BDL | *0.05-1.5* | *0.0004* |
| 5 | Fe | ND | ND | 1.2-2.0 | 0.6-0.8 | 0.003-0.02 | 0.003-0.02 | *0.3-1.0* | *0.0003* |
| 6 | Mn | 0.12-0.16 | ND-0.2 | 0.1-0.2 | 0.05-0.09 | 0.0001-0.009 | 0.0001-0.06 | *0.1-0.3* | *0.0001* |
| 7 | Ni | ND | ND | ND | ND | BDL-0.001 | BDL | *0.02* | *0.005* |
| 8 | Pb | ND-BDL | ND- BDL | 0.01-0.03 | 0.03-0.05 | ND | ND -0.009 | *0.01* | *0.009* |
| 9 | Zn | ND -0.1 | ND | 0.02-0.03 | 0.09-0.03 | 0.01 | 0.001-0.019 | *5.0-15* | *0.001* |

*Notes: BDL-Below detection limit; ND-Not detected*

TABLE 4
Zooplankton and Phytoplankton levels in Gosikhurd Reservoir and Upstream

| S N. | Parameter | Pre monsoon | | Monsoon | | Post monsoon | |
|---|---|---|---|---|---|---|---|
| | | Upstream water | Reservoir water | Upstream water | Reservoir water | Upstream water | Reservoir water |
| 1 | **Zooplankton/$m^3$** | 357-7536 | 179-3179 | 146-286 | 36-893 | 100-2167 | 200-968 |
| 2 | **Phytoplankton/ 100 ml** | 203906 - 360603 | 15318 - 525335 | 6780 -9040 | 502-8287 | 10045-19587 | 1758-8287 |

**Declaration**

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- The authors have no relevant financial or non-financial interests to disclose.
- The authors have no competing interests to declare that are relevant to the content of this article.

**Data availability statement:** The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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