Monitoring the contamination in the Gobind Ballabh Pant Sagar, Rihand, U.P. India
Sharma Pankaj¹, Kachhal Prabhakar¹, Beena Ananad¹, Vyas Sameer¹, Manorama Kaushal², Mahure N.V¹, Murari Ratnam¹
1- Central Soil and Materials Research Station, Olof Palme Marg, Hauz Khas, New Delhi, India.
2- Department of Environmental Engineering, Singhania University, Rajasthan, India
pan2256@gmail.com
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ABSTRACT

Gobind Ballabh Pant Sagar was created in 1962 on the river Rihand. The Dam is located in the state of Uttar Pradesh (24°12′9″N 83°0′29″E 24.2025°N 83.00806°E). It was commissioned for the purposes like irrigation, flood control, fishery and wildlife conservation etc. along with electricity generation. Availability of coal mines in the vicinity of the reservoir resulted into raising of many thermal power plants of different capacity. Apart from this abundance of electricity encouraged the establishment of various chemical industries around it. All these thermal power plants, coal mines and chemical industries use the reservoir water for various industrial purposes like cooling and discharging effluents. These operations contaminate the hydro-environment to some extent raising some concerns. For the purpose of monitoring the degree of pollution caused by ever growing industries, a long term detailed investigation program was initiated. The studies aim at establishing the degree of chemical pollution of reservoir water which will have multifold impacts on both biotic as well as abiotic components. The studies clearly indicate that further deterioration in the quality of the reservoir water has been arrested since monitoring of the quality of reservoir water was initiated. Constant monitoring of degree of pollution in the reservoir water has achieved in evoking a general mass awareness and control on the industries and TPPs to refrain from dumping the untreated effluents directly in the reservoir. This paper presents the details of the observations carried out in different seasons during August 2007 to October 2009.

Keywords: Chemical effluents, pH, conductivity, suspended matter, fly ash, pollution.

1. Introduction

Gobind Ballabh Pant Sagar (GBS), also known as Rihand reservoir was created in 1962 on the river Rihand, a tributary to Sone, which in turn joins the Ganga on its right flank. The river originates from the hills of Madhya Pradesh, draining a catchment of 13 344 km². Rihand Dam on it is located in the state of Uttar Pradesh (24°12′9″N 83°0′29″E 24.2025°N 83.00806°E). The reservoir has a capacity of 10 625 million m³ at the FRL of 268 m above MSL and a surface area of 46538 ha, which shrinks to 13759 ha at the dead storage (mean 30149 ha). It has a maximum length of 48 km and the mean depth at FRL is 22.8 m. Annual rate of inflow is estimated at 6 301 million m³.During Seventies, huge quantity of good quality coal was found at very shallow depths around and close to Rihand reservoir. Large quantities of readily available reservoir water and the abundant availability of coal from nearby open cast mines led to the installation of a number of thermal power plants (TPP) of
which five coal-fired thermal power plants, TPP A, TPP B, TPP C, TPP D and TPP E around it (Figure 1) have been selected for carrying out observations. Availability of electric power and other natural resources in the vicinity has encouraged the establishment of chemical industries (CHI) of which one at the north end of the reservoir which predominantly manufactures caustic soda, liquid chlorine and hydrochloric acid (Figure 1) is selected for observations. All the TPPs and CHI use water from reservoir for cooling and other purposes. Apart from this these industries has also been discharging their run off in the reservoir. The fly ash discharged by TPP ash ponds may abnormally increase the percentage of suspended solids in the reservoir waters. The heated water discharged from TPPs in the reservoir may increase the temperature of reservoir by 8 to 10°C from average reservoir water. The discharge from CHI add pollutants which change the chemical composition of reservoir water. These operations may be contaminating the hydro-environment thus raising some concern. For the purpose of monitoring the degree of pollution caused by ever growing industries, a long term detailed investigation program was initiated. The studies aim at establishing the degree of chemical pollution of reservoir water which may have multifold impacts on both biotic as well as abiotic components.

**Figure 1:** Location of TPPs, CHI and Sampling Points around Rihand Reservoir

### 1.1 Objectives of project

The multipurpose project had following main objectives:

- To develop an adequate progressive model for farming and industrialization in the east and the south-east UP.
- The electricity generated form it was to be used mainly in fifteen districts of the eastern and the south-eastern UP to run the tube-wells for irrigation of unirrigated agricultural land.
- Through this project the aim was to provide the irrigation facility to approximately 16 lac acres in U.P. and 5 lac acres in Bihar every year.
- Supply of electricity for the industries of cement, aluminum, chemical, fertilizers, chemical, porcline, paper, and other materialistic industries in U.P.
- Effective flood control
- Development of fishery and wild life conservation.
1.2 Anticipated problems

Some of the problems likely to be encountered in the project are

1. Decrease in the water holding capacity of reservoir.
2. Damage to concrete hydraulic structures.
3. Increase in average temperature of the reservoir water by 8 to 10 °C
4. Change in pH of reservoir water over a long period of time.
5. Decrease in aquatic life

1.3 Focus of investigation

Continuous monitoring of the quality of water has been carried out for assessing degree and rate of contamination. Following important aspects were taken into consideration during investigation

1. Quality of the water of incoming river
2. Quality of water in the reservoir at dam site
3. Quality of water in the immediate vicinity of the confluence of ash slurry from various TPPs and effluent from CHI with the reservoir water.
4. Quality of the ash slurry/chemical effluent water
5. Identifying the number of Ash slurry samples from TPPs going into the reservoir (TPPAS), Effluent samples from CHI going into the reservoir (ECHI) and Reservoir water from various locations (RW) conforming/not conforming to Central Pollution Control Board of India (CPCB) standard for emission or discharge of environmental pollutants, in a ash pond and ISI standards for potable water (Table 1).

Suspended solid contents and pH value of the various ash slurry and chemical effluent samples of thermal power plants and chemical factory for pollution studies was carried out apart from determining other chemical parameters.

2. Materials and Methods

In all twenty sampling locations (Figure 1) were selected for collection of TPPAS, ECHI and RW samples. The sampling locations are detailed in table 1.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Location</th>
<th>Sample No.</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TPP-A Ash Slurry Pond</td>
<td>8</td>
<td>RW Near TPP-A</td>
</tr>
<tr>
<td>2</td>
<td>TPP-B Ash Slurry Pond</td>
<td>9</td>
<td>RW Near TPP-B</td>
</tr>
<tr>
<td>3</td>
<td>TPP-C Slurry Pond</td>
<td>10</td>
<td>RW Near TPP-C</td>
</tr>
<tr>
<td>4</td>
<td>TPP-D Ash Slurry Pond</td>
<td>11</td>
<td>RW Near TPP-D</td>
</tr>
<tr>
<td>5</td>
<td>TPP-E Ash Slurry Pond</td>
<td>12</td>
<td>Rihand River- Main Bridge</td>
</tr>
<tr>
<td>6</td>
<td>CHI Chemicals Effluent</td>
<td>13</td>
<td>RW Near TPP-E</td>
</tr>
<tr>
<td>7</td>
<td>RW from Dam site</td>
<td>14</td>
<td>RW Near CHI</td>
</tr>
</tbody>
</table>

During the period from August 2007 to October 2009 in all 70 samples were collected. The samples were analyzed as per analytical procedure laid down in IS 3025-1986[6]. Wherever
necessary, reference was also made to the procedure laid down by American Public Health Association and Water Pollution Control Federation, USA\[7\].

2.1 Field Investigations

The in situ parameters viz. pH, Conductivity, Temperature, CaCO$_3$ Saturated pH, NH$_4^+$ and S$^{2-}$ of water samples collected from various locations were determined immediately after collection of each sample.

2.2 Laboratory Investigations

Detailed laboratory chemical analysis was carried out on water samples collected from various locations. Chloride, Sulphate, Bicarbonate, Carbonate, Calcium, Magnesium, Sodium, Potassium, Copper, Zinc, Manganese, Lead, Chromium and Iron content is determined using state of the Art equipments like Atomic Absorption Spectrophotometer, microprocessor based flame photometer, UV Visible Spectrophotometer etc. In addition, amount of suspended solids was also determined using gravimetric method.

3. Observations

3.1 Temperature

The observed insitu temperature for the TPPAs, ECHI and RW samples collected during different seasons is presented in Figure 2.

![](image1)

**Figure 2:** Insitu temperature of samples from various locations

3.2 pH values

pH values of the different types of samples is presented in Figure 3.

![](image2)

**Figure 3:** pH of samples from various locations
3.3 Conductivity values

The conductivity value for TPPAS, ECHI and RW samples is presented in Fig 4.

![Figure 4: Conductivity of samples from various locations](image)

3.4 Suspended solids

The observations are presented in Fig. 5.

![Figure 5: Results of suspended solids in the samples from various locations](image)

3.5 Carbonate (CO$_3^{2-}$) and Bicarbonate (HCO$_3^{-}$)

Concentration of Bicarbonate (HCO$_3^{-}$) in TPPAS and RW samples is found to be considerably low and varied between 30.5 to 122 mg/lit (figure 6).

![Figure 6: Results of bicarbonate content in the samples from various locations](image)
3.6 Chloride (Cl⁻)
Chloride (Cl⁻) concentration in TPPAS is found to be very low while that in five ECHI samples is very high (Fig 7).

![Figure 7: Results of chloride content in the samples from various locations](image1)

3.7 Sulphate (SO₄²⁻)
Sulphate (SO₄²⁻) concentration in TPPAS and RW samples ranged between 3.1 to 129.8 mg/lit. while that of ECHI samples varies between 67.9 to 305 mg/lit (figure 8).

![Figure 8: Results of sulphate content in the samples from various locations](image2)

3.8 Potassium (K⁺) and Sodium (Na⁺)
In TPAAS and RW samples concentration of K⁺ and (Na⁺) is considerably low (Fig 9, 10).

![Figure 9: Results of potassium content in the samples from various locations](image3)
Concentration of Sodium (Na\(^+\)) in ECHI samples is comparatively higher (Fig 10).

**Figure 10:** Results of sodium content in the samples from various locations

### 3.9 Calcium (Ca\(^{2+}\)) and Magnesium (Mg\(^{2+}\))

In all the TPPAS and RW samples Calcium (Ca\(^{2+}\)) and Magnesium (Mg\(^{2+}\)) are present in very low concentration (Fig 11). In ECHI samples their concentration of Calcium (Ca\(^{2+}\)), (figure 11) and Magnesium (Mg\(^{2+}\)), (figure 12) is found to be comparatively higher.

**Figure 11:** Results of Calcium content in the samples from various locations

**Figure 12:** Results of Magnesium content in the samples from various locations
3.10 Ammonium (NH$_4^+$)

Ammonium content of water samples collected from various locations was found to be nil. The ammonia level of such water drastically reduces$^{[2]}$.

3.11 Copper, Manganese, Iron, Lead, Chromium and Zinc

Heavy metals like copper, manganese, iron, lead, chromium, zinc are found absent or in very low concentration.

3.12 Total dissolved salts

The result of total dissolved salts for different samples is presented in figure 13.

![Figure 13](image-url)

**Figure 13:** Results of Total Dissolved Solids in the samples from various locations

4. Discussions of Results

4.1 Temperature

The main ecological consequences of heated water discharged by the TPPs into the aquatic ecosystem are increase in water temperature. In some cases, heated TPP discharge have elevated the water temperature by 8 to 10 °C$^{[2]}$. During the period of observations the average temperature of the TPPAS samples varied in the range 26.3 to 35.8°C, ECHI samples 26.9 to 35.1°C and that of RW samples between 24.3 to 36.4 °C. It is seen that in the present instance the temperature of reservoir in different seasons has not varied abnormally.

4.2 Assessment of pH, suspended solids, conductivity, total dissolved salts and chloride with respect to the standard parameters for discharge of environmental pollutants and potable water

Wastes emanating from an array of TPPs and CHI may cause pollution hazards and ecological damage in Indian reservoirs. Effluents from CHI discharged into Rihand reservoir are alkaline. Further it is high in total alkalinity, specific conductivity and chlorides$^{[1],[2]}$. Results of pH, suspended solids, conductivity, total dissolved salts and chloride for the tests conducted on the TPPAS, ECHI and RW$^+$ samples$^{[8]}$ are discussed w.r.t the standard
parameters for discharge of environmental pollutants and potable water (table 2). The assessment of these values w.r.t standard values is presented in table 3.

**Table 2:** Standards for discharge of environmental pollutants and potable water

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Standards of Emission or Discharge of Environmental Pollutants</th>
<th>Recommended range for potable water</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.5 – 8.5</td>
<td>6.5 to 8.5</td>
</tr>
<tr>
<td>Suspended solids, mg/l</td>
<td>100 max.</td>
<td>-</td>
</tr>
<tr>
<td>Conductivity µmhos/cm</td>
<td>-</td>
<td>Less than 1500 µmhos/cm</td>
</tr>
<tr>
<td>Total dissolved solid, mg/l</td>
<td>-</td>
<td>500 mg/l</td>
</tr>
<tr>
<td>Chloride, mg/l</td>
<td>-</td>
<td>200 mg/l</td>
</tr>
</tbody>
</table>

**Table 2:** Assessment of TPPAS, ECHI and RW Samples w. r. t. Recommended Standards

<table>
<thead>
<tr>
<th>Sample</th>
<th>Parameter</th>
<th>Observed range for the collected samples</th>
<th>Samples confirming to CPCB prescribed limits</th>
<th>Samples confirming to ISI prescribed limits</th>
<th>Samples exceeding prescribed limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPPAS</td>
<td>pH</td>
<td>6.46 – 8.81</td>
<td>22</td>
<td>3</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>Suspended solids, mg/l</td>
<td>66.2 – 3065.1</td>
<td>2</td>
<td>23</td>
<td>3</td>
</tr>
<tr>
<td>ECHI</td>
<td>pH</td>
<td>7.10 – 8.90</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Conductivity µmhos/cm</td>
<td>1152 – 4660</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total dissolved solid, mg/l</td>
<td>2367 – 3728</td>
<td>-</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chloride, mg/l</td>
<td>931 – 1910</td>
<td>-</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>RW</td>
<td>pH</td>
<td>6.86 – 8.63</td>
<td>34</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Conductivity µmhos/cm</td>
<td>71.3 – 277</td>
<td>40</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total dissolved solid, mg/l</td>
<td>77 – 192</td>
<td>40</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chloride, mg/l</td>
<td>4 – 32.5</td>
<td>35</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Suspended solids, mg/l</td>
<td>0 – 1013.0</td>
<td>29</td>
<td>11</td>
<td></td>
</tr>
</tbody>
</table>

**4.2.1 Assessment of pH**
Dissolved gases affect the pH of water. The overall pH range of natural water is generally between 6 and 8. Industrial wastes may be strongly acidic or basic and their effect on pH values of receiving water depends on the buffering capacity of water. pH of TPPAS, ECHI and RW Samples w. r. t. Recommended Standards is presented in Table 3. pH of most of the samples confirmed to their respective standard limits.

4.2.2 Conductivity

Specific conductance yields a measure of water’s capacity to convey an electric current. This property is related to the total concentration of the ionized substances in water and the temperature at which the measurement is made. The nature of the various dissolved substances, their actual/relative concentrations, and the ionic strength of the water sample vitally affects the specific conductance. The conductivity of ECHI samples is high which indicate high soluble salt content. Out of 5 samples 3 samples exceeds the limits (Table 3). The conductivity value for TPPAS and RW samples are low indicating low concentration of soluble salt content. These values confirm to prescribed standard conductivity limits.

4.2.3 Suspended solid content

The most deleterious impacts of thermal pollution is the blanketing effect on the reservoir bed. Fly ash covers extensive areas of the bottom which in long run may result in blanketing off the substratum. The values of suspended solid content of 23 out of 25 TPPAS samples exceeded the CPCB limits (Table 3). Inspite of high suspended solids in TPPAS, only 11 out of 40 RW samples exceeded the limits, which indicates the precautions adopted by the TPPs for putting the ash slurry in the reservoir

4.2.4 Chloride (Cl–)

Chloride (Cl–) concentration in ECHI samples exceeds the prescribed limit(Table 3). Inspite of such high (Cl–) concentration in ECHI, even the RW sample 14 which is collected from reservoir area near CHI has very low Chloride (Cl–) concentration. All other RW samples also have very low Chloride (Cl–) concentration.

4.2.5 Total dissolved salts

Total dissolved salts in TPPAS samples is low. For all the 40 RW samples it is well with in prescribed limits. In ECHI samples total dissolved salts for all the 5 samples is found to be very high.

5. Conclusion

The discharge of contaminants from TPPs and CHIs in the GBS contaminate the hydro-environment to some extent raising some concerns. Sensing these concerns as raised by many authors a long term detailed investigation program was initiated for the purpose of monitoring the degree of pollution caused by ever growing industries. The studies clearly indicate that further deterioration in the quality of the reservoir water has been arrested since monitoring of the quality of reservoir water was initiated. Constant monitoring of degree of pollution in the reservoir water has achieved in refraining the surrounding TPPs and CHIs from dumping the untreated effluents directly in the reservoir.
Acknowledgement

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6. References


4. Standards for Emission or Discharge of Environmental Pollutants, in a ash pond effluent - Pollution Control Acts, Rules and Notifications, (1996), by Central Pollution Control Board, India.


