IMPACT OF COAL MINING ON WATER QUALITY IN MANGKOLEMBA REGION UNDER MOKOKCHUNG DISTRICT NAGALAND, INDIA

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Received October 09, 2015 Accepted February 10, 2016

ABSTRACT

Coal is one of the most exploited minerals in the region. The usual method for coal extraction is predominantly rat-hole mining while open cast mining is employed to a lesser extent. Most of the mining activities are small scale ventures controlled by individuals, private parties or landowners. Coal mining undoubtedly generated wealth and employment opportunity in the area but simultaneously has led to environmental degradation. The water bodies are the greatest victims of the coal mining. The variations of physicochemical parameters of rivers and stream in the area were studied. Samples were collected from six main affected water sources. The collected samples were then analyzed viz, temperature, pH, Electric Conductivity (EC), Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Salinity, ORP, sulphate, total hardness, calcium hardness. Contaminations of Acid Mine Drainage (AMD) originated from mining activities are the major causes of degradation of water quality in the area. Low pH, high electrical conductivity, high TDS, high concentration of sulphate, Low Dissolved Oxygen (DO) are some of the physicochemical parameters which characterize the degradation of water quality.

Key Words: Coal mining, Water quality, Physicochemical parameters, Acid Mine Drainage, Contamination, WHO

INTRODUCTION

The North-east is the land of green belt of India, so called land of forest and tribals, the entire North-east region is rich in its natural resources-oil, natural gas, minerals and most importantly valuable forests.\(^1\) Nagaland is one the North-eastern states of India which possesses rich deposits of minerals and abundant natural resources. The state is endowed with moderate deposits of coal, having prognostic reserve of about 316.41 million tonnes.\(^2\) Mangkolemba region is one of the regions in Nagaland which is blessed with rich natural resources. Of these, coal is one such resource which can uplift the economy of the people and the state if utilized in proper scientific manner. At present, extensive coal mining is being carried out in the region. Ever since the Nagaland Coal Policy 2006 came into force, the Department of Geology and Mining, Nagaland, India has issued sufficient Coal Prospecting Licenses (CPL) and Coal Mining Leases (CML), including short term Small Pocket Deposit Licenses (SPDL), thereby bringing many mines under licensing policy of the state. However, un-planned extraction of coal is still being carried out by private parties or landowners at many places especially in Mokokchung, Wokha, Dimapur, Mon, Longleng and Peren districts of Nagaland.\(^2\) Coal extraction in the region is done by a method commonly known as rat-hole mining as well as open cast method. Most of the mining activities are small scale ventures controlled by individuals who own the land. Mining operation undoubtedly generated wealth and employment opportunity in the area but simultaneously has led to extensive environmental degradation and disruption of traditional values in the society. Environmental problems associated with mining operation have been felt severely because of the region’s fragile ecosystems and rich biodiversity. Removal of top soil, denudation of forest cover, degradation of agricultural lands, scarcity of water, pollution of air, water and
soil are some of the significant environmental implications of coal mining.\textsuperscript{1-3} Besides, a vast area has become physically disfigured due to haphazard dumping of overburden, caving in of the ground and subsidence of land. The water bodies of the area are the greatest victims of the coal mining. Intense exploitation of surface and ground water, burning of coal and leaching of metals from coal-ash tailing due to mining operation are some of the root causes for anthropogenic contamination of water quality.\textsuperscript{4}

The problems of water quality degradation and its adverse impacts on availability of potable and irrigation water, soil quality, agricultural productivity and biodiversity in the area have been increasing and attracting people's attention. The most significant environmental issue that has arisen in the mining industries over the last two decades is that of Acid Mine Drainage or Acid Rock Drainage (AMD/ARD) originated from tailing dumps and waste pyrite usually found with valuable metal sulphides such as galena mined rock piles.\textsuperscript{5}

The primary cause of degradation of water quality and the declining trend of biodiversity in the water bodies of the mining area is attributed mainly to the Acid Mine Drainage (AMD) which makes water highly acidic and rich in heavy metal concentration.\textsuperscript{6}

AMD is formed by a series of complex geochemical and microbial reactions that occur when water comes in contact with pyrite (iron sulfide) found in coal and exposed rocks of overburden. Mine drainage is generated when pyrite reacts with air and water to produce sulphuric acid and dissolved iron.\textsuperscript{2}

The oxidation of pyrite and overall chemistry of AMD formation is summarized below:

\[
4 \text{FeS}_2 + 11 \text{O}_2 = 2 \text{Fe}_2\text{O}_3 + 8 \text{SO}_3
\]

Pyrite + Oxygen = Ferric Oxide + Sulphur dioxide

\[
4 \text{FeS}_2 + 15 \text{O}_2 + 14 \text{H}_2\text{O} = 4\text{Fe(OH)}_3 + 8\text{H}_2\text{SO}_4
\]

Pyrite + Oxygen + Water = Ferric Hydroxide ↓ + Sulphuric acid (Yellow precipitate)

During the process of pyrite oxidation, dissolved Fe\textsuperscript{2+}, SO\textsuperscript{2-}\textsuperscript{2-} and H\textsuperscript{+} followed by the further oxidation of the Fe\textsuperscript{2+} to Fe\textsuperscript{3+} are formed. Some or all of this iron can precipitate to cause turbidity of water (in the form of the red, orange or yellowish colour) and sedimentation at the bottom of streams. The acid runoff or AMD aggravates the problem further by dissolving heavy metals such as aluminum, copper, lead, mercury etc. found in rocks and soil. As a result, the AMD contaminated surface water is not only acidic but also rich in various inorganic metals.\textsuperscript{7}

**AIMS AND OBJECTIVES**

To assess the impact of coal mining on water quality of rivers and streams situated in and around the coal mining areas of Mangkolemba through analysis of selected water quality parameters and to compare the results with the BIS and WHO standard. And to suggest some environmental management strategies that can be useful in mitigation of the water problems associated with mining operation for the health and well being of the people and to save the region’s rich ecosystem and biodiversity from further degradation.

**MATERIAL AND METHODS**

**Study area**

Mangkolemba is a town and sub-division under Mokokchung district of Nagaland, India. It is situated between Japukong and Changkikong ranges at an altitude of 870 mts and is located between the coordinates of 26\degree 29'55"N latitude and 94\degree 26'11"E longitude. The town is the sub-divisional headquarter of three ranges, namely, Changkikong, Japukong and Tsurangkong covering about 40 villages.\textsuperscript{8} Bounded by rivers and mountains, the valley is noted for its rice production. The region has rich deposits of minerals including coal. However, extensive unplanned extraction of coal is being carried out at many places in the region thereby degrading the region fragile ecosystem especially the water bodies. Therefore, it is felt that the status of water quality of rivers and streams in the coal mining areas need to be assessed for the health and well being of the inhabitants.

**Sampling and analysis**

The water samples were collected seasonally (pre-monsoon and post-monsoon) from the six main affected rivers and streams covering five blocks of the region for one year 2014-15. Samples were collected from the stretch of about 1-2 kms away from the mining area.
Samples were collected and properly packed using 1L polythene container and was insured that the representative samples reflect the main water bodies. Analysis of physicochemical characteristics viz., pH, ionic conductivity, temperature, TDS, salinity, ORP were done using portable water analysis kit (Eutech model cyperscan, Singapore) and digital water analysis kit (Eutech model cyperscan, Singapore) at the sampling site. Dissolved Oxygen (DO) was done by Winkler’s iodometric titration method, total hardness, calcium hardness by compleximetric EDTA method, Sulphate concentration by gravimetric analysis following mainly the standard method.9,14

RESULTS AND DISCUSSION

Study revealed that many rivers and streams that drain the undulating landscape of the region are badly affected by Acid Mines Drainage (AMD) originating from mining operation. Contamination of water sources is evident by its colour which in many cases appear brownish to reddish orange. Low pH, high ionic conductivity, high TDS, higher sulphate concentration, low dissolved oxygen are some of the physicochemical parameters which characterize the degradation of water quality. The extent of degradation of water quality is discussed below:

Total hardness

Total hardness is the parameter of water quality used to describe the effect of dissolved minerals mostly Ca and Mg.10 The hardness of water is not a pollution parameter but indicates water quality mainly in terms of Ca$^{2+}$ and Mg$^{2+}$ expressed as CaCO$_3$. Hardness sometimes is attributed due to sulphates or chlorides of iron, manganese and aluminum.11,14 In this study, the water quality was found to be moderately hard in the ranges 136-180 mg/L in few study samples S1, S3 and S4. (Table 1 to Table 3)

Sulphate

The presence of sulphates in water is mainly due to iron sulphide present in coal and rocks and its reaction with water and oxygen. As pyrite wastes are chemically broken down, sulphate ions are produced in runoff water. Sulfuric acid is mainly responsible for acidity of the contaminated water. Elevated concentration of sulphates ranges from 57 to 173 mg/L were found in the samples S1, S2, S3 and S4 (Table 1) the highest being the source Mechanchut (S1) in the range of 168 mg/L (Table 3).

Table 1 : Seasonal values of physicochemical characteristics of surface water in coal mining area of Mangkolemba sub-division under Mokokchung district, Nagaland, India

<table>
<thead>
<tr>
<th>Sample code</th>
<th>Sources</th>
<th>Season</th>
<th>Sulphates mg/L</th>
<th>Total hardness mg/L</th>
<th>Calcium hardness mg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>Mechanchut</td>
<td>post-monsoon</td>
<td>163-173</td>
<td>178-181</td>
<td>69-74</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pre-monsoon</td>
<td>159-164.6</td>
<td>178-180</td>
<td>66-72</td>
</tr>
<tr>
<td>S2</td>
<td>Zaong</td>
<td>post-monsoon</td>
<td>81-86</td>
<td>87-94</td>
<td>32-37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pre-monsoon</td>
<td>81-85</td>
<td>87-90</td>
<td>32-36</td>
</tr>
<tr>
<td>S3</td>
<td>Longben</td>
<td>post-monsoon</td>
<td>59-64</td>
<td>137-139</td>
<td>53-55</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pre-monsoon</td>
<td>61.72</td>
<td>136-140</td>
<td>52-56</td>
</tr>
<tr>
<td>S4</td>
<td>Atzutepuba</td>
<td>post-monsoon</td>
<td>57-68</td>
<td>159-161</td>
<td>49-58</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pre-monsoon</td>
<td>57.61</td>
<td>158-160</td>
<td>51-58</td>
</tr>
<tr>
<td>S5</td>
<td>Tenemtzuuyong</td>
<td>post-monsoon</td>
<td>13-23</td>
<td>40-43</td>
<td>12.2-17</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pre-monsoon</td>
<td>11.5-17</td>
<td>40-42</td>
<td>11.6-16.5</td>
</tr>
<tr>
<td>S6</td>
<td>Diphuyaayong</td>
<td>post-monsoon</td>
<td>12.1-15</td>
<td>31-38</td>
<td>12.1-17</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pre-monsoon</td>
<td>12-14.1</td>
<td>30-36</td>
<td>13-17</td>
</tr>
</tbody>
</table>

ISSN 0973 – 6921 ; EISSLN 2319 – 5983
Journal of Environmental Research And Development Vol.10 No. 03, January-March 2016
Table 2: Seasonal values of physicochemical parameters of surface water in coal mining area of Mangkolemba sub-division under Mokokchung district, Nagaland, India

<table>
<thead>
<tr>
<th>Sample code</th>
<th>Sources</th>
<th>Season</th>
<th>pH</th>
<th>Conductivity µmho/cm</th>
<th>TDS ppm</th>
<th>Salinity ppm</th>
<th>DO mg/L</th>
<th>ORP mv</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>Mechangchut</td>
<td>post-monsoon</td>
<td>3.0-3.6</td>
<td>681-1090</td>
<td>435-712</td>
<td>752</td>
<td>14.5</td>
<td>325</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pre-monsoon</td>
<td>2.9-3.2</td>
<td>690-1045</td>
<td>447-749</td>
<td>783</td>
<td>15.4</td>
<td>343</td>
</tr>
<tr>
<td>S2</td>
<td>Zaong</td>
<td>post-monsoon</td>
<td>3.4-4.2</td>
<td>181-234</td>
<td>98-146.3</td>
<td>202</td>
<td>15.6</td>
<td>258</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pre-monsoon</td>
<td>3.3-4.0</td>
<td>178-227</td>
<td>97-151</td>
<td>204</td>
<td>16.4</td>
<td>262</td>
</tr>
<tr>
<td>S3</td>
<td>Longben</td>
<td>post-monsoon</td>
<td>3.2-3.6</td>
<td>265-654</td>
<td>117-254</td>
<td>273</td>
<td>16.1</td>
<td>296</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pre-monsoon</td>
<td>3.1-3.4</td>
<td>289-687</td>
<td>121-298</td>
<td>293</td>
<td>17.8</td>
<td>311</td>
</tr>
<tr>
<td>S4</td>
<td>Atzu Tepuba</td>
<td>post-monsoon</td>
<td>5.6-5.9</td>
<td>298-321</td>
<td>178-191</td>
<td>287</td>
<td>15.8</td>
<td>152</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pre-monsoon</td>
<td>5.4-5.9</td>
<td>299-334</td>
<td>181-212</td>
<td>286</td>
<td>16.7</td>
<td>161</td>
</tr>
<tr>
<td>S5</td>
<td>Tenemtzuyong</td>
<td>post-monsoon</td>
<td>4.8-5.4</td>
<td>62-88.9</td>
<td>45-58.3</td>
<td>83</td>
<td>16.2</td>
<td>140</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pre-monsoon</td>
<td>4.7-5.3</td>
<td>67-91</td>
<td>48-67</td>
<td>91</td>
<td>16.3</td>
<td>152</td>
</tr>
<tr>
<td>S6</td>
<td>Diphuya Ayong</td>
<td>post-monsoon</td>
<td>4.8-5.2</td>
<td>63-87</td>
<td>39-54.6</td>
<td>78</td>
<td>16.5</td>
<td>156</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pre-monsoon</td>
<td>4.9-5.2</td>
<td>74-93</td>
<td>47.7-67</td>
<td>87</td>
<td>16.8</td>
<td>157</td>
</tr>
</tbody>
</table>
Table 3: Average values of water quality parameters of surface water in coal mining area of Mangkolemba sub-division under Mokokchung district, Nagaland, India

<table>
<thead>
<tr>
<th>Sample code</th>
<th>Sources</th>
<th>pH</th>
<th>Conductivity µmho/cm</th>
<th>TDS ppm</th>
<th>Salinity ppm</th>
<th>DO mg/L</th>
<th>ORP mv</th>
<th>Sulphates mg/L</th>
<th>Total Hardness mg/l</th>
<th>Calcium hardness mg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>Mechangchut</td>
<td>2.9</td>
<td>885</td>
<td>501</td>
<td>752</td>
<td>14.5</td>
<td>325</td>
<td>168</td>
<td>180</td>
<td>72</td>
</tr>
<tr>
<td>S2</td>
<td>Zaong</td>
<td>4.1</td>
<td>231</td>
<td>146.3</td>
<td>202</td>
<td>16.4</td>
<td>258</td>
<td>82.3</td>
<td>90</td>
<td>36</td>
</tr>
<tr>
<td>S3</td>
<td>Longben</td>
<td>3.4</td>
<td>455</td>
<td>213</td>
<td>288</td>
<td>17.7</td>
<td>296</td>
<td>61.72</td>
<td>140</td>
<td>56</td>
</tr>
<tr>
<td>S4</td>
<td>Atzu Tepuba</td>
<td>5.9</td>
<td>321</td>
<td>191</td>
<td>281</td>
<td>16.7</td>
<td>152</td>
<td>57.61</td>
<td>160</td>
<td>58</td>
</tr>
<tr>
<td>S5</td>
<td>Tenem tzuyong</td>
<td>5.3</td>
<td>88.9</td>
<td>58.3</td>
<td>83</td>
<td>16.3</td>
<td>140</td>
<td>13</td>
<td>40</td>
<td>16</td>
</tr>
<tr>
<td>S6</td>
<td>Diphuya Ayong</td>
<td>5.2</td>
<td>83.6</td>
<td>54.6</td>
<td>78</td>
<td>16</td>
<td>156</td>
<td>12</td>
<td>36</td>
<td>14</td>
</tr>
</tbody>
</table>
The colour of many water sources in the study area appeared brownish to reddish orange. Siltation of coal particles, sand, soil, contamination of AMD and formation of ferric hydroxide are the major causes of changes in water colour (Fig.1(a) and Fig.1(b)). Ferric hydroxide [Fe (OH)$_3$] is a commonly formed insoluble inorganic substance in water bodies of the coalfields. It is this material that stains streams and is responsible for brownish to reddish orange colored water.$^{12,14}$

**Fig. 1(a)**: Brownish colored water of Mechangchut stream due to mining activities

**Fig. 1(b)**: Contamination of surface water, Zaong stream from acid mine drainage, brownish colored water of Zaong stream due to mining activities


Electrical Conductivity (EC)

Conductivity is the measure of the capacity of a solution to conduct electric current. It is a rapid measure of the total dissolved solids present in ionic form.\(^{14}\) In this study, the conductivity was found highest in the streams Mechangchut (S1) in the range 681-1070 µmho/cm\(^{-1}\) and Longben (S3) with 265-687 µmho/cm\(^{-1}\) (Table 2) the average value of samples S1 and S3 being 885 µmho/cm\(^{-1}\) and 455 µmho/cm\(^{-1}\) respectively (Table 3).

pH

The pH of a water body is very important in the determination of water quality since it affects other chemical reactions such as solubility and metal toxicity.\(^ {15,16}\) pH values is controlled by the equilibrium of CO\(_2\), CO\(_3\) and HCO\(_3\). Contamination of Acid Mine Drainage (AMD) leads to acidity or low pH of the affected water bodies. Acidic water is a matter of primary concern since, it can directly be injurious to aquatic organisms. It also facilitates leaching of toxic metals into the water that could be hazardous to aquatic life, directly or can disturb the habitat after precipitation. During the study period higher pH value was recorded in post-monsoon and lower in pre-monsoon The pH of almost all the water samples under study was found to be highly acidic in the ranges of 2.9 to 4.8 (Table 2) the most acidic being the sample Mechangchut (s1) with pH 2.9 (Table 3). For drinking water, a pH range of 6.0-8.5 is recommended.\(^ {17-19}\)

Total Dissolved Solids

Total dissolved solid is the amount of solid present in water. The dissolved solid in natural water mostly consist of bicarbonates, carbonates, sulphates, chlorides, nitrates, phosphate of calcium, magnesium, sodium and potassium with traces of iron, manganese and other substances.\(^ {20}\) Dissolve solid causes foaming in boilers, accelerate corrosion and affect the colour and taste of many finished product. In this study, the TDS was found highest in stream Mechangchut (s1) in the range of 435-749 ppm. (Table 2 and Table 3)

Dissolved Oxygen (DO)

DO is an important limnological parameter indicating level of water quality and organic pollution in the water body.\(^ {21}\) The value of DO is remarkably significant in determining the water quality criteria of an aquatic system. In the system where the rates of respiration and organic decomposition are high, the DO values usually remain lower than those of the system, where the rate of photosynthesis is high.\(^ {22}\) Dissolved oxygen is essential for sustaining higher life forms in water. Dissolved oxygen was found to be on the lower range in some water samples although it was within the permissible limits. The lowest being the source Mechangchut (S1). (Table 2 and Table 3)

Salinity

Salinity is a measure of dissolved salts in given volume of water. Salinity and conductivity show almost the same relationship in all the water body of the study area. Electrical conductivity is directly proportional to the salt concentration and vice versa. The value of salinity and total alkalinity provides idea of natural salts present in water.\(^ {23}\) Salinity and total alkalinity of water is due to presence of mineral salt present in it. It is primarily caused by the carbonate and bicarbonate ions .\(^ {24}\) The constituent leading to high alkalinity are mostly inorganic and organic wastes.\(^ {25-29}\) The salinity fluctuated in accordance with the fluctuation in the pollution load.\(^ {30,31}\) Salinity value was highest in winter followed by summer and monsoon.\(^ {32}\) During monsoon lower values of salinity was due to dilution of river water with rain water.\(^ {33,34}\) Elevated levels of salinity were found in the samples S1, S3 and S4 in the ranges 281-752 ppm. (Table 2 and Table 3).

CONCLUSION

The study revealed that many water sources of Mangkolemba region are unprotected and contaminated by Acid Mine Drainage (AMD) which originated from coal mining operation. Degradation of water quality in the area is evidenced by low pH, high ionic conductivity, high TDS and higher sulphate concentration. As a result, the rivers and streams which supported extremely rich biodiversity and traditional agriculture and were sources of potable and irrigation water in the area now carry contaminated water. Under prevailing conditions of water quality, there is an urgent need for initiating activities for eco restoration.
of the affected areas. Filling of abandoned mines, shifting of coal depot from the nearby river bank, extensive afforestation, neutralization of acidic seepage, conservation of top soil, scientific management of AMD and water resources etc. will go a long way in restoration of the lost environmental glory of the region.

ACKNOWLEDGEMENT

Author thankfully acknowledge to the Chemistry Department, Kohima Science College, Jotsoma, Nagaland, India for providing infrastructural facilities.

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