Impact of Kudremukh Iron Ore Mining on Bhadra River Ecosystem

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Abstract—*In December 2005, India's largest iron ore mining operation in Kudremukh National Park, headed by Kudremukh Iron Ore Company Limited (KIOCL), was terminated as it was proven to have had severe detrimental impacts on the forest ecosystems along the river Bhadra in Chikkamagaluru district of Karnataka. This study conducted over 3 weeks, analyses the impact of iron ore pollution on the freshwater river ecosystems of the Bhadra river 9 years post the termination of the mining.*

The main site of study was at Balehole, Chikkamagaluru. Samples were taken from sites along the river at Jamble, Kudremukh to compare the impact of the direct and runoff iron pollution. Past studies were used as benchmarks to estimate the rate of recovery of environment.

The main parameters of this study are:

***Extent of iron penetration** around the river bank, was calculated by measuring the distance up to which significant iron pollution was seen. The river bank was dug to calculate the depth at which iron settling was visible.*

***Presence and absence of flora and fauna** was studied and a correlation and cause study done on the observational data acquired.*

***Inhabitation capacity of soil and water** was measured by conducting a Biochemical Oxygen Demand (BOD) test on the water, running a pH test on soil, and culturing bacteria from soil samples.*

Local fishermen were interviewed for their opinions and experiences of the impact of mining on their livelihoods.

The study concludes that the inhabitation capacity of environment has highly decreased. Statistical proof suggests that the biomagnification of iron in biotic species has had chronic impacts on the organisms, including the eradication of certain aquatic species. The scope for this project lies in finding potential bioremediation methods to improve the rate of recovery of the environment.

1. INTRODUCTION

Open cast mining has proven to have a severe detrimental effect on forest ecosystems. Its effects are the worst on downstream sites of rivers, where the silt load increases by an enormous amount, consequently decreasing the water holding capacity of the river. Its consequences include loss of freshwater life, like fish. .It also threatens the health of humans and large mammals that use the rivers as a watering hole or as fishing sites. The fish are subject to morphological damage by the iron present in the water [11] and many diseases can hence cross the species barrier when these fish are eaten by other animals. There is also a noticeable loss of plant life as many plants are unable to grow in these polluted conditions. During monsoon seasons, in rainforests especially, the iron penetrates the soil to a great depth as it settles with the silt into the river bed, thus eradicating many non-chordate species as well [14].

The Western Ghats, situated in South West India, is officially one of the 25 biodiversity hotspots of the world (Myers et al., 2000) and includes about 325 globally threatened species. The Kudremukh iron ore mine is located in a region of the Western Ghats that receives more than 6000 mm of rainfall annually [1], hence the potential for contributing to sediment loading in downstream water bodies and damaging endangered ecosystems is high.

The Kudremukh Iron Ore Company Limited (KIOCL) conducted its mining operations for over 20 years. This iron ore mine, the largest in India, was designed to produce 22.6 million Mg of crude ore annually. As the venture expanded, road construction and mining activity downstream of the designated site were carried out.In 1987, the 600 km^2 Kudremukh National Park (KNP) was established to preserve the rich biodiversity in the area, which include many endangered endemic species including the tiger, the Great Hornbill and the Lion Tailed Macaque (Karanth, 1985; Karanth, 1992; Karanth et al., 2001). The Bhadra river originates at Gangamoola in Kudremukh National Park and flows east, joined by its tributaries the Somavahini near Hebbe, Thadabehalla and Odirayanahalla. It flows through the towns of Kudremukh, Kalasa, Hornadu, Balehonnur, Balehole, and Narasimharajapura. The Bhadra dam is built across the river near Lakkavalli which forms the Bhadra reservoir (with a catchment area of 1968 km^2). The Bhadra reservoir irrigates more than 1000 km^2 of agricultural lands and generates more than 33 MW of hydropower [1].

However, since 1985, there had been increasing cause to worry about the impact of mining on the water quality (Rao, 1987) and ecosystems of the Bhadra river and fast increasing sediment loading in the Bhadra reservoir (Irrigation Department, 1987), which the officials of the Karnataka State Government and the Government department concerned with irrigation had been repeatedly expressing. The Centre for

Ecological Science of the Indian Institute of Science (IISC) investigated the impacts of mining water quality of the river and the flora and fauna of the forest (CES, 2001). The reports unfortunately revealed little about the water quality due to the samples not being taken during the monsoon months, when the rivers carry as much as 85% of the annual sediment load.

Centre for Wildlife Studies, Wildlife Conservation Society and other environment and wildlife conservation oriented organisations and individuals in partnership with the Water Resources Department of the Government of Karnataka proved that as a result of the mining, the sediment load in the Bhadra River had dramatically increased.They narrowed the source of the sediment load down to a very small fraction of the watershed area, comprising the KIOCL mining site. They laid out figures estimating the increase in sediment load from 1, 197 tons in 1984 to 49, 429 tons in 1986. The supreme court thus ordered the closure of KIOCL operations in Kudremukh by 2005 [1] [6] [8].

However, they stressed upon the importance of restoration. Enough damage had been done to suggest that the environment would take a long time to recover. In many regions within KNP and other nearby forests, such as Bhadra Wildlife Sanctuary, the devastating effects of the iron ore deposits and high amount of silt load during the monsoon especially, can still be seen.

This study focuses on analysing this impact after 9 years of termination of mining. Two sites, one in Kudremukh National Park and one in Bhadra Wildlife Sanctuary were taken into consideration for this study. Both sites are separated by a distance of 32 km, hence this study will focus on a comparison between the pollution in Bhadra river, upstream and downstream of the site of mining. The study sites spanned across a distance of 3 km at each venue. The study focuses on

A) Water quality testing

B) Estimation of iron concentration on river bank

C) Effect of iron in soil on plants and animals (observational analysis)

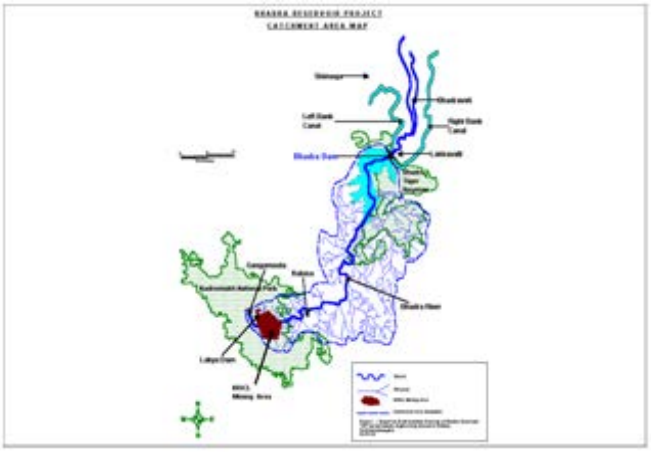
D) Impact of iron concentration in water on the livelihood of fishermen

The aim of this project is to collect the data, study the effects of pollution on the environment and brainstorm for measures that can be taken to accelerate its rate of recovery.

2. STUDY SITE

2.1 Background

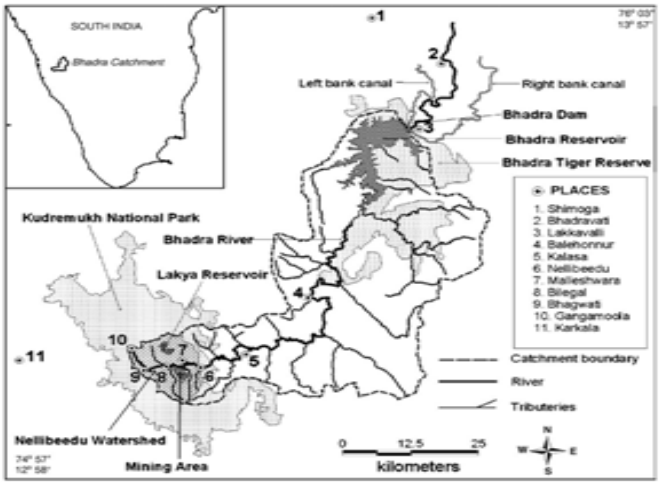
In 1976, the Karnataka Iron Ore Company Limited was established at the upper catchment of the Bhadra river. The mining project was leased an area of around 46 km^2, becoming the largest mining initiative in India, and was designed to produce 22.6 million Mg of crude iron ore annually [6]. As the company sought to increase the prospective yield, roads were constructed through the forest and mining activity started to move downstream of the designated site.



Source: Centre for Wildlife Studies

In 1987, the second largest protected region in the Western Ghats, the Kudremukh National Park was established, covering an area of over 600 square kilometres of shola grasslands and evergreen forests. The region receives around 7000 mm of rainfall every year and has thus created a large number of perennial streams, forming Tunga, Bhadra and Netravathy rivers. This area is part of the high priority (level-one) global level tiger conservation unit that is recognised by the Wildlife Conservation Society and the World Wildlife Fund.

2.2 Physical setting



There were two sites taken into consideration, one in Bhadra Wildlife Sanctuary, and one in Kudremukh National Park to compare the ecosystem impacts of iron pollution at the region where the river originates and where the river nearly drains.The two sites were Ballehonnur and Malleswara respectively, and were chosen as they coincided with the same study sites where a past study was done on the impacts of mining before the termination of the operation [1].

In Ballehonnur, a catchment area known as Balehole was taken as it was secluded from human inhabitation and relatively deeper into the forest area, interspersed with areas of sandy/ clayey land and rocky terrain.In Malleswara, a catchment area known as Jamble was considered for study. It was also a region where there was very sparse human inhabitation and was situated close to the iron mines.Both the sites are separated by a distance of 32 km. At each site, a distance of 3 km was taken and samples were taken at relatively regular distances to get a mean value of all the environmental parameters considered for the area.

3. SAMPLE COLLECTION AND METHODOLOGY:

The samples were collected over a 5 day period from the 20th to the 25th of December 2014. Apart from the DO_1 testing for the BOD calculation, no tests were run in Chikkamagaluru. All tests were run in Bangalore, in the Christ University Laboratories. Samples were stored, while in Chikkamagaluru, under optimum conditions and were all stored in airtight, sealed containers.

3.1 Sample Collection

3.1.1 Water

The water was collected in sterilised, air-tight, 500ml plastic bottles and stored away from sunlight. The samples were collected at a 1 meter depth. Three samples were taken at each site so that a mean BOD value could be calculated for the water quality of each area.

3.1.2 Soil

3.1.2.1 Balehole

Samples were collected at 0 km, 0.5 km, 0.9km and 2.5 km along the distance of the study site.At each site, the river bank was dug to approximately 2-3 ft depth and soil was collected in airtight ziplock bags.

3.1.2.2 Jamble

It was difficult to collect soil samples at Kudremukh as the terrain was covered by large sedimentary rock and the foundation was powdered rock, entirely magnetic. One sample was collected for visual comparison purposes and for magnetic testing but no pH tests run on it. The soil was tested for iron using a magnets that were placed within the river bed and the river bank.

No samples of plant cover or aquatic life were collected this time as the study focuses entirely on an observational analysis.

3.2 Methodology

3.2.1 Extent of iron penetration

The extent of iron sedimentation on the river bank was gauged length wise and depth wise.

A measuring tape was used to measure the distance up to which significant iron pollution was seen from the edge of the river bank into the forest cover.

The riverbank was also dug at various points along the course of the 3 km study site and the depth at which pure iron settling was visible in the river bed was recorded.

3.2.2 Water testing

A Biochemical Oxygen Demand test was conducted on the water samples to measure the amount of oxygen metabolised by microorganisms within a system over a 5 day incubation period. It indirectly pertains to the number of microorganisms being sustained by the system.

$$BOD = \frac{DO1 - DO5}{p} \text{ x1000 mg/L}$$

The BOD test is used to measure waste loads to treatment plants, determine plant efficiency (in terms of BOD removal), and control plant processes. It is also used to determine the effects of discharges on receiving waters.

The DO_1 test was conducted in the field station on the day of sample collection. The DO_5 test was conducted in Bangalore, 5 days post the collection of the samples.

3.2.3 Soil testing

The pH test was chosen to be conducted as acidic soils, iron toxicity tends to occur as anaerobic bacteria reduce iron to its soluble Fe^{2+} form. These soils are generally water-logged, poorly aerated, and plants growing in them exhibit signs of bronzing. Soluble iron is found in soils at pH 6.3 in more than 1000 ppm. [12] [13]

The soil tests were done 8 days post the sample collection. A calibrated pH meter was used to conduct the experimentation.

3.2.4 Presence and absence of flora and fauna

The same 3 km stretching each study site was walked 5 times from morning to evening and all animals seen were recorded. Plants were observed for abnormalities and growth conditions.

3.2.5 Interview of local fishermen: A random set of 4 fishermen were interviewed in Ballehonnur. There was no pre-decided parameter's of meeting. Locals were asked where the nearest group of traditional fishermen could be found. Shankara, Jadish, Nagaraja and Shekara were questioned in general about their experiences with the mining project and how it has affected their lives.

4. RESULTS

4.1 Extent of iron penetration

4.1.1 Balehole

At 0.9km and 1.5 km along the study site, the river bank was dug about 1.2 metres from the river. At a depth of 2 ft from the surface of the soil, significant iron sedimentation was observed and the concentration of iron increased with depth.

The extent of significant iron pollution across the river bank was 62 ft (breadth) until which the banks were black with iron. The iron sedimentation decreased steadily past this point and there was an increase in tree growth as well.

4.1.2 Jamble

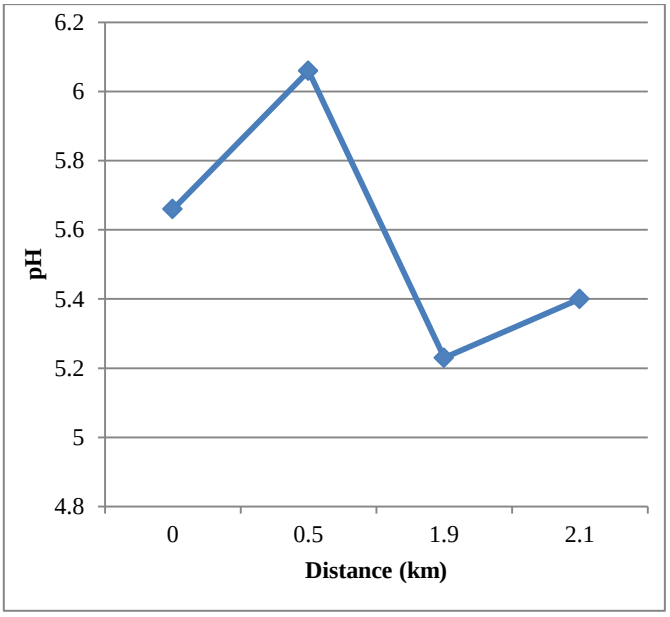
The Jamble site was based on sedimentary rock. Hence the land could not be dug. However, magnetic tests were run to check the extent of iron penetration. Magnets were placed inside the river bed and on the river bank. Results showed that the entire river bank was magnetic. There was heavy iron sedimentation in the river bed as well.

4.2 Water testing

SITE	SAMPLE NUMBER	DO1(mg/l)	D05(mg/l)	BOD_5
Balehole	**1**	**18**	**6.6**	
	2	**17**	**6.3**	
	3	**19**	**6.8**	
	Average	**18**	**6.56**	**11.44**
Jamble	**1**	**14**	**6.5**	
	2	**14**	**6.6**	
	3	**14**	**6.7**	
	Average	**14**	**6.6**	**7.6**

4.3 pH testing

Balehole



4.4 Study of flora and fauna

4. 4.1 Fauna

Presence of amphibian and reptilian life including frogs, toads and snakes observed. Many arthropods identified including water scorpion, cockroaches, beetles, etc, were seen.

Many bird species were identified. Piscivores were few but included black capped night heron, common kingfisher, black capped kingfisher, lesser egret, cormorant, coots, spotted billed ducks, grey heron etc.

Fish population was lower than expected. However, since the study was conducted over only a 5 day period, many species could have been missed. The decrease in fish population can be theoretically speculated and the evidence provided by the fishermen allows us to correlate decreasing fish numbers to the mining.

4.4.2 Flora

Vegetation was sparse where pollution concentrations were higher. The plants growing near the river bank were stunted in their growth and the number of plant species observed increased greatly as the pollution concentration in the soil was seen to decrease further away from the river.

Bronzing was seen in the plants growing within the 62 ft parameter. Algal growth was abundant on water surface. Wild orchids were observed on trees growing near the river.

4.5 Interview of local fishermen

According to the fishermen:

- The daily catch has reduced from 20kgs to around 2-3kgs.
- -Some species of the fish that werefound earlier are no longer present in the river.
- -Even compared to last year, the fish count has reduced by about 50%.
- -The fish count has reduced despite the fact that the usage of pesticides in surrounding areas has been curbed.

The validity of the information can be scrutinized as the values given by the fishermen (e. 50% annual decrease in fish count etc.) cannot be taken at face value. However, the experiences of the fishermen cannot be disregarded as although the values may be investigated, the impact that the mining has had on their livelihood must be considered true.

5. DISCUSSION

Although a quantitative estimate of the rate of recovery of the environment cannot be made as statistics along the same parameters were not calculated immediately post the termination of the mining, qualitatively, the state of the environment seems to have improved very little from 9 years ago. The iron sediment load, especially in Balehole was concentrated to the point where the river bank as well as the lower layers of the river bed were black. Magnetic tests in Jamble revealed that all the rocks were magnetic and high concentrations of iron were also found in the river bed beneath a surface layer of soil.

The pH tests done on the soil reveal an increase in iron toxicity from upstream to downstream. Soluble Fe^{2+} yielded by the iron metabolising bacteria have caused bronzing in plants and stunted vegetation in those areas. Presence of wild orchids suggests that the trees are not getting enough nutrition as orchids only grow in damaged environments. BOD values indicate moderate pollution levels according to standards set by the Environment Protection Agency. Low dissolved oxygen levels correspond to the steady decrease in fish count, as verified by the fishermen. The absence of many piscivores can be correlated to decreasing fish numbers.

Chikkamagaluru, being primarily a fishery and agricultural district depends entirely on the river as their source of revenue. The effect of high iron concentration in the water, potentially forming compounds in its oxidized state with other more harmful elements such as lead, on the agricultural lands, is also a concern. There are some bioremedies to iron toxicity which are implemented on a small scale basis in privately owned agricultural lands such as planting of high iron metabolising plants including cabbages. Other interventions such as magnetic filtration can also be looked into.

6. CONCLUSION

From this study, we can conclude that restoration measures must be implemented at the earliest. These include a quantitative investigations of:

1) Water quality
2) Impact of water quality on biotic freshwater ecosystem
3) Impact of this pollution on economic status of locals of Chikkamagaluru district and alternatives that can be offered to make up for the decreasing fish yield
4) Iron concentration in soil

It is essential that bioremediation methods are explored to accelerate the rate of recovery of the environment. Due to the abundance of fossil fuel sources and minerals, there are many sites along the Western Ghats where mining was a huge threat to the forest ecosystems. Sedimentation of reservoirs resulting from forest degradation in this area is a problem of increasing concern (Babu et al., 2000). Many of these mining projects have been stopped at present, however, the devastating effects of the mining still persist. It is not enough to stop the mining operations. It is imperative that efforts are made to repair the damage done to the environment.

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