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Original Article

Degradation of Water Quality by Mining Effluents: Its Impact on *'Puntius Narayani'*

Nandini Vaz Fernandes

Abstract

Unregulated mining causes pollution of air, land and water. Mining effluents are the main source of degradation of water bodies in their vicinity. *Aim:* The present study was designed to determine the change in the water quality on account of mining activity and its effect on the growth and development of the fishes. *Settings and Design:* Water bodies in four mining areas were selected for the study. Upstream site of the river was taken as a measure of uncontaminated water as compared to down stream site which had influx of mining effluents from the surrounding mines. *Methods and Material:* Catch sampling method was used to compare the parameters in the upstream and downstream sites of eight study sites. Water samples were evaluated for physicochemical parameter and heavy metals. Fishes from these sites were examined for body length, width and weight. Gills, liver and muscle tissues of these fishes were examined for heavy metals. *Statistical analysis used:* The statistical significance of associations between various qualitative parameters was evaluated through Fisher's exact test. *Results:* The study showed degradation of water quality because of the influx of mining effluents in the downstream sites. Physicochemical parameters significantly altered were turbidity, total suspended solids and sulphates in the downstream sites. The metals detected were iron, copper, zinc, manganese, cadmium and nickel. Examination of the fishes revealed decrease in the body weight of the fishes in the downstream site as compared to the upstream site. *Conclusions:* We attribute the impaired growth of fishes to the synergistic effect of change in water quality and increase in heavy metal concentration in the downstream region on account of mining effluents.

Keywords: Mining Effluents; Heavy Metals; Impaired Growth in Fishes.

Introduction

Mining is the major economic activity of Goa. The mining belt of Goa covers an area of approximately 700 sq.kms. Mining has been a very important element in the economic history of modern Goa and a significant foreign exchange earner for the state. It has provided the trigger to boost the economy of the mining talukas. However, unregulated mining of both small and large-scale mining operations are inherently disruptive to the environment, producing enormous quantities of waste that can have deleterious impacts for decades. The mine wastes constitute a potential source of contamination to the environment, as heavy metals and acid are released in large amounts (Ledin M et al., 1996). Aquatic pollutants produce multiple consequences at the organism, population, and community and ecosystem level, affecting organ function, reproductive status, population size, species survival and thus biodiversity. Besides altering the water quality, mining activity is also contributing release of heavy

Author's Affiliation: Associate Professor & Head, Department of Zoology, Parvatibai Chowgule College (Autonomous), Gogol, Margao, Goa 403601, India.

Corresponding Author: Nandini Vaz Fernandes, Associate Professor & Head, Department of Zoology, Parvatibai Chowgule College (Autonomous), Gogol, Margao, Goa 403601, India.
E-mail: nvf001@chowgules.ac.in / nandini_chgrl@yahoo.com

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metals. Therefore assessment of water quality around mining areas is essential as all aquatic organisms are directly or indirectly affected by the physical characteristics of their environment, especially the chemical composition of the water. The high concentration levels, damage tissues and interfere with the normal growth, proliferation, and reproduction (Gillis et al., 2008). The data available on the degradation of water bodies on account of mining in Goa is restricted. Therefore the present study was undertaken to determine the change in water quality on account of mining activity, by comparing the physicochemical parameters of water samples collected from upstream and downstream sites and analyzing the effect of the change in water quality on the growth of fish Puntius narayani.

Materials and Methods

Four study areas of Kalay, Ponda, Codli and Rivona in south Goa, were identified using GPS / Google maps. From each area, we identified two sampling sites. The upstream and the downstream location of the river from each area were considered for sample collection. Selection of sampling site was based on the location of the influx of effluents from the nearby prominent mines. Sampling point which was located four kms upstream of the mining area was meant to establish the water quality before the influence of mining activities. The 'upstream' region was thus considered to be a reflection of water condition devoid of mining effluents. Downstream site of the river was considered as the second site for sample collection as it had visible sources of influx of mining effluents. Catch sampling method was used to compare the parameters in the upstream and downstream site. Water samples and live fishes were collected from the upstream and downstream sites of the four sampling areas. The study involved analysis of all physicochemical parameters of water in upstream and downstream regions of Kalay, Ponda, Codli and Rivona. The water samples were also subjected to heavy metal analysis. The heavy metal analysis was done by atomic absorption spectrophotometer. Heavy metals tested included iron, manganese, arsenic, lead, zinc, mercury, copper and hexavalent chromium. Physicochemical parameters analyzed were pH, turbidity, temperature, conductivity, biochemical oxygen demand, carbonates and bicarbonates, dissolved oxygen, phosphates, nitrates, sulphates and free carbon dioxide. Fishes collected from the upstream and downstream site were analyzed for body size, body length, and weight. The gills, liver, and muscles were also evaluated for detection of heavy metals. The tissue samples obtained from Puntius narayani, dried, powdered, digested according to standard procedure of Sreedevi et al. (1992) and analyzed using Atomic Absorption Spectrophotometer. The standardized procedures used for heavy metal detection in the tissues was as per IS 3025 Part 53: 2003, SOP/ITG/AAS/INST-01. Values of heavy metals were recorded in mg/ltr. The data was tabulated analyzed statistically. The statistical significance of associations between various qualitative parameters was evaluated through Fisher's exact test (two tail). Online calculators of statistic were used for standard deviation at www.easycalculation.com and fisher's test at www.graphpad.com.

Results

The main ores extracted in these regions include iron, basalt, and manganese. The selection of the sampling areas was based on the presence or absence of effluents released by the mines into the water body.

Analysis of Water

The water samples of the upstream and downstream of the 04 study areas were analyzed for physicochemical parameters and heavy metals.

Physicochemical Parameters

The physicochemical parameters that the water samples were tested for include the Ph, Colour, Odour, Turbidity, Total Hardness as $CaCO_3$, Total Dissolved Solids, Sulphates as SO_4, Nitrates as NO_3, Total Alkalinity as $CaCO_3$, Conductivity, Total Suspended Solids, Bio-Chemical Oxygen Demand, Chemical Oxygen Demand, Residual Chlorine, Calcium as Ca and Fluorides as F. In the present study the physicochemical parameters which were significantly altered in the downstream sample were turbidity, total suspended solids and sulphates (Table 1). Others factors affected were lowered pH, conductivity, temperature, hardness, carbon dioxide, salinity, nitrates and BOD. However, the increases or decrease was statistically insignificant.

Heavy Metals in Water

The metals detected in the water samples of eight sites were Iron, Copper, Zinc, Manganese, Cadmium, and Nickel. Test for Lead and Boron were negative.

Table 1: Physicochemical parameters in the upstream and downstream sites of the 04 study areas

Sr. No	Parameter	Unit	Kalay	Ponda	Rivona	Kodli	Remark
1.	pH		U-6.98 D-6.87	U- 7.48 D- 7.48	U- 7.15 D- 7.33	U- 7.85 D- 7.27	Decreased pH in the downstream sites *(p=1.000).*
2.	Color	Hazen	U-5 D-5	U- 5 D- 5	U- 5 D- 5	U- 5 D- 5	reddish tinge in the downstream
3.	*Turbidity	NTU	U-1.4 D-13	U- 5.17 D- 20.3	U- 0.97 D- 3.15	U- 2.98 D- 3.49	increased significantly *(p=0.001)* in the downstream
4.	Total Hardness as CaCO3	mg/ltr	U-14 D-13	U- 23.09 D- 23.33	U- 21.23 D- 25.29	U- 40.27 D- 12.25	decreased level of conductivity in the downstream *(p=1.00)*
5.	Total Dissolved Solids	mg/ltr	U-47 D-50	U- 50 D- 45	U- 51 D- 52	U- 52 D- 40	Higher in upstream
6.	Chlorides as Cl	mg/ltr	U-11.7 D-12.9	U- 10.65 D- 10.65	U- 14.2 D- 14.2	U- 21.3 D-17.75	--
7.	Calcium as Ca	mg/ltr	U-8.12 D-11.1	U- 5.61 D-6.81	U- 7.21 D- 9.22	U- 12.42 D- 13.21	---
8.	Magnesium as Mg	mg/ltr	U-1.83 D-1.5	U- 2.19 D-1.46	U- 0.73 D- 0.49	U- 2.19 D- 1.7	--
9.	Sulphates as SO4	mg/ltr	U-1.93 D-2.9	U- 1.23 D- 1.75	U- 2.98 D- 3.33	U- 0.88 D-1.58	Higher concentration in downstream *(p=0.4065).*
10.	Nitrates as NO3	mg/ltr	U-0.18 D-0.24	U- 0.18 D-0.23	U- 0.08 D-0.13	U- 0.09 D-0.1	Higher concentration in the downstream *(p=0.5795).*
11.	Total Alkalinity	mg/ltr	U-19 D-19	U- 17 D-17	U- 17 D-18	U- 35 D-29	--
12.	Conductivity	µs/cm	U-52.14 D- 54.98	U- 69.52 D-67.73	U- 60.25 D-63.75	U- 103.6 D-73.84	Decreased conductivity in the downstream
13.	*Total suspended solids	mg/ltr	U-ND D-2	U- 1 D-7	U- ND D-1	U- ND D-7	Significantly higher in the downstream *(p= 0.0001).*
14.	BOD	mg/ltr	U-0.8 D-0.6	U- 0.8 D-0.8	U- 0.9 D-0.9	U- 1 D-1	--
15.	COD	mg/ltr	U- 4 D- 3	U- 3.96 D-3.96	U- 4 D-4	U- 3.95 D-3.95	--

Abbreviations: U- upstream; D-downstream; ND- not detected; BDL - below detectable level

Table 2: Showing fish body length, width and weight in the 08 sites

Study Area	Study Site	Body Length (Cms)	Body Width (Cms)	Weight (Gms)	Metals Detected In Water
Kalay	SITE 1 (U) SITE 2 (D)	4.1 ±0.29 3.12 ±0.43	1.18 ±0.15 1 ± 0.16	0.29 ±0.07 0.21 ±0.03	Fe Fe, Cu, Zn, Mn
Usgao	SITE 3 (U) SITE 4 (D)	4.18 ±0.78 4.07 ±0.43	1.25 ±0.89 1.13 ±0.24	0.63 ±0.42 0.59 ±0.19	Fe, Cu, Zn, Mn, Cd Fe, Cu, Zn, Mn
Rivona	SITE 5 (U) SITE 6 (D)	4.25 ±0.60 3.96 ±0.13	1.25 ±0.23 1.24 ±0.09	0.63 ±0.40 0.55 ±0.13	Fe, Mn Fe, Mn
Kodli	SITE 7 (U) SITE 8 (D)	3.77 ±1.21 3.23 ±0.97	1.42 ±0.55 1.17 ±0.40	0.89 ±0.90 0.48 ±0.24	Fe, Cd, Ni Fe, Mn

*U- Upstream sites, D- Downstream sites

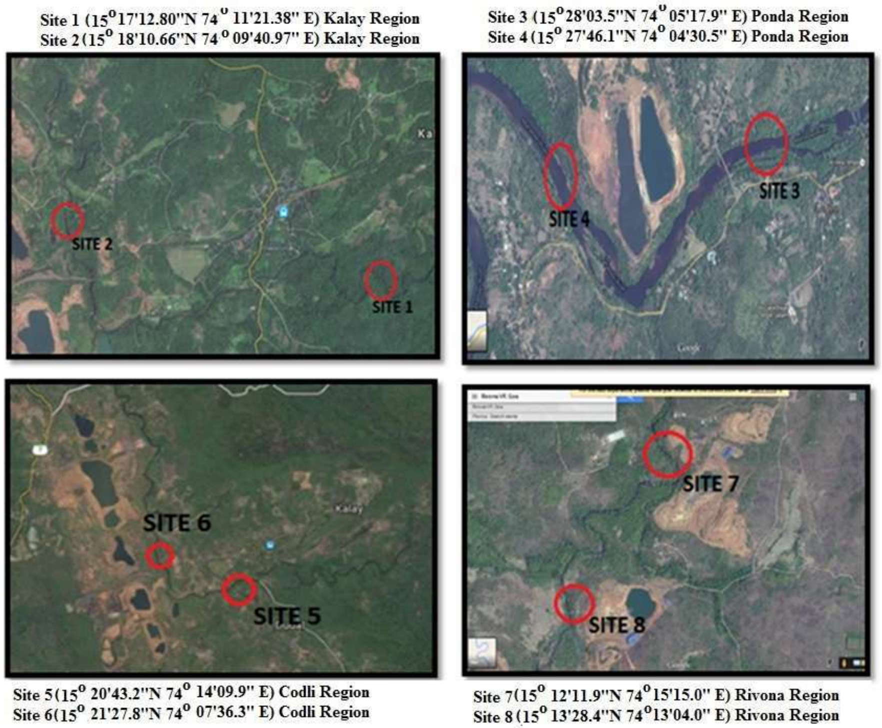

Fig. 1: Eight study of the four sampling areas in Kalay, Ponda, Codli and Rivona

Table 3: Bioaccumulation factor of the different metals in the tissues of *Puntius narayani*

Metal	Bioaccumulation Factor (BAF) in Tissues				
Iron	Gill (15.3)	>	Muscle (1.5)	>	Liver (0.86)
Copper	Gill (79.8)	>	Liver (8.2)	=	Muscle (6.4)
Zinc	Liver (47.3)	>	Gill (41.6)	>	Muscle (24.3)
Manganese	Liver (373)	>	Gill (100.3)	>	Muscle (23.5)
Cadmium	Gill (10.8)	=	Muscle (0.71)	>	Liver (0.35)
Nickle	Muscle (4.0)	=	Liver (3.7)	>	Gill (0.01)

Iron, zinc, and manganese were the most common metal pollutants detected in higher concentrations in the water bodies at the mining sites. The types of metals and their concentration varied at different sites (Fig. 1). There was a significant increase in the concentration of Copper, Iron and Zinc in the downstream samples in all the four study areas.

Analysis of Fish – Puntius narayani

The fishes collected from the upstream and downstream sites of the four sampling areas were studied.

Body Length and Body Weight

The average body length, width, and weight of the fishes in the downstream site were decreased as compared to the fishes in the upstream sites (Table 2). Significant reduction in body weight was observed in the fishes of the downstream region ($p= 0.02$).

Tissue Wise Distribution of Metals in Puntius Narayani

The Gill, Liver, and Muscle tissues of the fish Puntius narayani were studied for the deposition of the metals. The tissues were evaluated for various metals. We found deposition of iron, copper, zinc, manganese, cadmium, and nickel in the tissues. The study showed interesting findings of tissue preference of these metals (Table 3).

Gills: We observed that gill tissue showed higher metal deposition as compared to the liver and muscles. Analysis of the gills revealed presence of all metals studied. We observed high concentrations of Zinc, Manganese, copper and iron in the gill tissues. The Tissue preference was Zinc ≥ Manganese ≥ copper > iron. Assessment of bioaccumulation factor (BAF) showed many folds increase of Iron, copper and cadmium in the gills.

Liver: Liver tissue revealed presence of all metals studied. We observed high concentrations of Manganese, Zinc, copper and iron in the liver tissues. The Tissue preference was Manganese ≥ Zinc ≥ copper > iron. Assessment of bioaccumulation factor (BAF) showed many folds increase of manganese and zinc in the Liver.

Muscles: Compared to the gill and the liver, the muscles showed less concentration of most of the metals. Assessment of bioaccumulation factor (BAF) showed that muscles showed a tendency to accumulate nickel.

Discussion

The present study shows that the mining effluents degrade the water quality by altering the physicochemical parameters. The heavy metals released are a major concern for the humans as there is deposition of metals in the tissues of the fishes. The concentration of total suspended solids (TSS) in the water sample from the downstream sample was significantly higher as compared to the upstream sample. TSS can increase because of organic particles from decomposing organic material and chemical precipitates. Since the BOD was not altered significantly we attribute the increased TSS, to the chemical precipitates. Studies of Berli et al., 2014, shows that increases TSS can have a negative effect across multiple scales of fish communities, from individual level to the system-level.

The turbidity of the downstream sample was found to be significantly higher as compared to the upstream sample. Turbidity increases in river and lake water mainly due to floating algae, soil washing from banks and industrial activities such as mining. Turbidity in the present sites was due to the mining as other causative factors were not observed. The turbidity seen may be due to the increased TSS and also the constant disturbance of water with the mining effluents. Large amounts of suspended solids and clay materials from mining effluents contribute to the turbidity which can clog the gills of fish species (Hickin, 1995). It is also hazardous to the fish population as it can smother fish eggs and suffocate benthic organisms.

The present study showed increased concentrations of nitrates and sulphates in the water samples of the downstream site though it was found to be statistically insignificant. Nitrates provide nutrition for algae leading to an increase in their growth and demand for dissolved oxygen. This decreases the amount of dissolved oxygen present for other aquatic organisms. Nitrites are intermediates in the oxidation of ammonia to nitrates. It is a well-known toxicant for fish as well as a disruptor of multiple physiological functions including iron regulatory, respiratory, cardio-vascular, endocrine and excretory processes. Nitrite accumulation causes oxidation of haemoglobin to methaemoglobin compromising blood oxygen transport (Kroupova et al., 2005).

Heavy metals released in the water bodies through the mining effluents may be at levels below their toxic thresholds. Though the metals present in the water were in small quantities, the consequence of it on the aquatic organisms is of importance because of bioaccumulation. Metals enters into the organs through the respiratory and the integumentary system. Due to their non-degradable nature, such sub-lethal concentrations may still pose the risks of damage via uptake and subsequent bioaccumulation. Examination of the fishes from the upstream and downstream region revealed a decrease in the body weight of the fishes in the downstream site as compared to the upstream site. The reduction in body size and weight may be due to environmental stress experienced by the fish on account of metals such as iron and zinc as well as some physicochemical parameters of the water such as turbidity and suspended solids. The change in the water quality can be attributed to the mining effluents. Studies of Schoenfuss et al., 2008; Giesy and Dobson, 2000, Fernandes NV, 2015) also revealed that exposure to mining effluents can lead to abnormal physiological responses and cause adverse effects on the development, growth, behaviour, and reproduction of fish. The present study showed interesting findings on the risk posed to humans on account of metal deposition in the tissues of the fishes. The study showed interesting findings of tissue preference of these metals. Gill tissue showed higher metal deposition as compared to the liver and muscles. Metal deposition in the muscles was the least. These differences result from different uptake, deposition and excretion rates. The gills are considered the main site of entry for the dissolved metals. Thus they represent the target for the toxic action of some metals. Another explanation for finding high concentration in gill is mucous excretion by this organ. The excreted mucous has affinity to be bound with metal ions. We conclude that Zinc, manganese, copper and Iron have tendency to be deposited in the gills because the entry of these metals may be more through the surface exposure. The present study also showed that Liver had greater affinity to concentrate manganese and zinc. The liver is considered the main detoxifying organ. Manganese accumulation in the liver tissue may be due to biogenic materials especially phytoplankton's readily incorporating the metals in them and transferring to the fishes through the various trophic levels. Deposition of these metals may be attributed to the cumulative effect of the quantity of these metals ingested by the fishes through the food chain, and the ability of the fishes to digest these metals or transport it to the liver for detoxification. Constant exposure of the fishes to the metals on account of the continuous leaching of the metals from mining effluents will lead to significantly high levels of these metals which can apparently have chronic effects on fishes. Since fish is one of the major components of the human diet, the deposition of these metals may lead to bioaccumulation and is, therefore, a matter of grave concern. In humans, the presence of even trace heavy metals in diets can cause serious health problems ranging from neuro-, nephro-, carcino, to immunological disorders, if ingested over a long period of time (Tanee, et al., 2013; Uwem et al., 2013). Therefore, though the metals present in the water were in small quantities, the consequence of it on the aquatic organisms is of importance because of bioaccumulation.

Conclusion

Synergistic effect of the change in water quality and an increase in heavy metal concentration in the downstream region on account of mining may be the possible cause of impaired growth of fishes indicated by the reduction in body length and weight of the fishes and genetic damage. Though the increase in each of the physicochemical factor is low, the interplay of all factors in totality can impose severe stress on the body metabolism of the fishes, thereby acting as an impediment to body growth. The present study is a small reflection of the consequences of environmental degradation on account of mining effluents. The larger picture encompasses the damage to air, water, and land on account of unregulated mining. Therefore it is recommended that mining effluents should be treated specially to remove metals before releasing into the water bodies and that bioaccumulation studies should be component of environment impact assessment for renewal of mining leases.

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Conflicting Interest: None.

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Key Messages

We recommend that mining effluents should be treated especially to remove metals even if they are in traces, before releasing into the water bodies as it may lead to health hazards on account of bioaccumulation and biomagnifications. Environmental impact assessment should include bioaccumulation studies for renewal of mining licences.

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