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EFFECTS OF COAL MINING ON FISHES OF MEGHALAYA, INDIA: A REVIEW

PRIYAM NATH [a*], ADITY DEKA [a] AND MANOJ TALUKDAR [a]
[a] Department of Zoology, Gauhati University, Guwahati, India.

AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration among all authors. Author PN did the secondary data collection. Author AD did the analysis of data. Author MT did the compilation of study. All authors read and approved the final manuscript.

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Review Article

ABSTRACT

Coal mining activities generate huge quantity of effluent containing tremendous amount of several metals, nitrate, sulphate, dissolved, and suspended solids as well as other harmful pollutants. These toxic effluents are regularly being released into the neighbouring ponds, lakes and rivers. Significant discharge of untreated coal mining effluent into the aquatic environment contributes to a variety of toxic effects on aquatic fauna including fish. Coal mining activities specifically in the region of Meghalaya located in North-east India is posing severe threats to the aquatic biota. The purpose of the paper is to pay special emphasis on the fish fauna that lives in this region that has large effluents of acid mine drainage. Many authors have previously described the different histopathological changes in a fish that suffer from severe toxicity of acid mine drainage. This study has been prepared taking into account the various works of different authors and is thus a review of their work. The whole aim of the study is to give a general idea that acid mine drainage from coal mines has tremendous impact on the fish fauna and may completely wipe out the population that thrives therein in the long run.

Keywords: Coal mining; fish; Meghalaya; toxicity.

1. INTRODUCTION

"Coal, commonly called the black gold of India contributes extensively in the economic growth of the country and is widely used for energy production" [1]. "Coal mining activities have tremendously increased in India with increase in energy requirements and ranks third among top ten coal producing countries" [2]. "Coal mining activities generate huge quantity of effluent which contains tremendous amount of several

**Corresponding author: Email: priyam9296@gmail.com;*

metals, nitrate, sulphate, dissolved, and suspended solids as well other harmful pollutants" [3]. "These toxic effluents are regularly being released into the neighbouring ponds, lakes and rivers affecting the biological integrity of the aquatic environment that thrives therein. The heavy metals are of great concern due to their toxicity and non-biodegradability in animal tissues. They bio-accumulate and bio-magnify in the tissues of living organisms via food chain" (Malik et al., 2010 [4]; Authman et al., 2015 [5]; Ali and Khan, 2018 [6], 2019 [7]). "Acid Mine Drainage lowers the pH of the receiving streams under the tolerance range, and will effect the growth and reproduction" [8]. "Discharge of untreated coal mining effluent (CME) into the aquatic environment leads to a variety of toxic effects on aquatic fauna including fish" (Talukdar et al., 2017 [9]; Lakra et al., 2019 [10]). "Fish have the ability to absorb and concentrate water-soluble heavy metals directly from the surrounding water through epithelia, gills, digestive tract and skin [5] and for this reason coal mining effluent has a tremendous impact on fish". "Heavy metals that accumulates in tissues produces histopathological alterations in different organs like the gills, liver, kidney, and skin which are responsible for impairment of vital functions like respiration, excretion, and reproduction" [11]. "Feeding on fish cultured in toxic effluent-fed pond water leads to human exposure to toxic metals posing serious threat to human health due to their bio magnification over the time" (Yap et al., 2015 [12]; Osa-Iguehide et al., 2016 [13], Ali & Khan, 2018 [6], 2019 [7]).

Coal mining activities specifically in the region of Meghalaya located in North-east India is posing severe threats to the aquatic biota. It is evident that fish fauna in these regions are declining day by day due to two main reasons; firstly coal mine activities lead to acid mine drainage (AMD) directly into the river and secondly dumping of coal for auction on its bank resulting in excessive accumulation of AMD. As a result of which, the river is devoid of any aquatic organism seasonally in some area of the aforementioned region [14]. Keeping in view the above mentioned problems, this study was prepared so as to give a general idea on the impact of of acid mine drainage on fish fauna that thrives in this region. The work was carried out in order to give a notion to the general public that if this activity of coal mining along with AMD continues, the population of fish fauna may be completely wiped out in the long run. The people's safety prospect was also kept in view while preparing this report.

2. METHODOLOGY

The worldwide web databases were referred during the study. The information was extracted and data obtained were duly scrutinized and thoroughly checked by assessing the sites under study. The sites were duly visited by the authors and local experts were consulted as to confirm the validity of the data and whether the statements hold true in the current study.

3. RESULTS AND DISCUSSION

3.1 Historical Background and Current Situation of Coal Mining in Meghalaya, North-East India

"Coal mining was initiated in North-East India by Medlicott in 1869 and 1874" [15]. "Coal occurrence in Jaintia hills were examined by Dias in 1962-63 and Goswami and Dhara in 1963-64 which was carried out through drilling methods" [16]. Meghalaya, one of the eight north-eastern states of India possesses rich deposits of coal. The coal deposits in the state are distributed in Khasi Hills, Garo Hills and Jaintia Hills. The exploitation of coal for commercial purposes started in Khasi Hills of Meghalaya during the 19^{th} century. During that time most of the coal deposits were few and isolated, so were later left to the local miners as it was not amendable to conduct scientific mining in the organized sector. Later on the local miners accepted coal mining as one of their customary rights. "From Khasi Hills these illegal mining activities spread out to other parts of the state, viz., Jaintia Hills and Garo Hills in the beginning of the 1970s" [17].

"Jaintia Hills District of Meghalaya is also a major producer of coal. The areas of extensive coal mining in the district as reported by Swer & Singh, [18] are Sutnga, Lakadong, Musiang-Lamare, Khliehriat, Ioksi, Ladrymbai, Rymbai, Bapung, Jarain, Shkentalang, Lumshnong and Sakynphor". "Though mining operation has brought wealth and employment opportunity in the area, but simultaneously it has also led to extensive environmental degradation and disruption of traditional values in the society [18]. Some of the effective environmental implications of coal mining include large scale denudation of forest cover, scarcity of water, pollution of air, water and soil and degradation of agricultural lands" (Das Gupta et al., 2002 [19]; Swer & Singh, 2004 [18]). "Some of the areas in Khasi Hills district as reported by Sarma, 2005 [15] were Laitryngew, Cherrapunjee, Laitduh, Mawbehlarkar, Mawsynram, Lumdidon, Langrin, Pynursla, Lyngkyrdem and Mawlong-Shella-Ishamati. In Garo Hills coal mining was carried out in West Darrangiri, Siju, Pyndengru-Balpakram and Selsela Block" [15].

During a report submitted before the National Green Tribunal of Meghalaya, it was brought into account that the mining activity in Garo, West Khasi and East Jaintia Hills was being carried on without permission from any governmental authority or body. The activity was neither being supervised nor scientifically regulated by any authority under the state or the State Pollution Control Board. “Despite of the regulatory laws like Environment (Protection) Act, 1986, the Water (Prevention and Control of Pollution) Act, 1974 and the Air (Prevention and Control of Pollution) Act, 1981, Mines and Minerals (Development and Regulation) Act, 1957 which were already in force in this area, the people were carrying on illegal coal mining activity without paying any heed to the government. Even the state Government did formulate a mining policy in the year 2012 (The Meghalaya Mines and Minerals Policy, 2012) whereby mining activity was to be carried on in consonance with law and the statutory provisions” (The Gazette of Meghalaya, 2012 [20]). The whole emphasis was that coal mining was accepted as a customary activity which has been in force for so many years and the people have unquestionable right to carry this illegal mining activity without complying to any of the environment or regulatory laws. It was contended during the report that the major sources of revenue of the locals were the royalty assets that was received from the State which was recovered from the mining activity. “It was further contended that significant number of people were dependent for their livelihood on the coal related activities and if the transport of already extracted coal was also prohibited, it would cause serious damage to the economy and hurt the livelihood of the people of the state of Meghalaya” (Orders of the Tribunal, The Original Application No. 13/2014 and Original Application No. 73/2014) [21].

According to a report submitted by Asad R. Rahmani [22] (Director of Bombay Natural History Society) to the Standing Committee of the National Board for Wildlife, Government of Meghalaya in 2010, there has been illegal coal mining in the areas around Balpakram National Park and no lease or permission has been sought under various mining related laws such as the Mines and Minerals (Development and Regulations Act, 1957, and Coal Mines (Nationalization) Act, 1973. However despite these illegal activities, none of the judiciary councils have taken any action as to stop it. It was further mentioned in the report that most of the coal particles finally landed up in the streams and rivers. The report mentioned about the presence of 4 sites around the Balpakram Baghmara landscape at which illegal coal mining was going on namely, Chitmang Gongrot and Halwa Atong Aking, Siju Wildlife Sanctuary and Siju caves, Rangtangsora and Rongsu Agal.

3.2 Minerals of High Concern to Aquatic Fauna

Coal contains a significant amount of ferrous sulphate, which is available in the form of pyrites. During the process of mining, pyrite is exposed to atmospheric oxygen, resulting in an oxidation process in which pyrite is converted into ferrous sulphate and sulphuric acid in the presence of bacteria [18]. The reaction involved in the formation of AMD as given by Swer & Singh, [18] are as follows:

$$4\ FeS_2 + 15\ O_2 + 14\ H_2O = 4\ Fe(OH)_3\downarrow + 8\ H_2SO_4$$

Pyrite + Oxygen + Water = Yellow precipitate↓ + Sulphuric Acid

This sulphuric acid lowers the pH of water in the aquatic environments. Another hazardous element found in coal in small amount is Selenium [23]. When coal-bearing strata are exposed to air and water and when coal is washed before transport and distribution, selenium gets mobilized. Once mixed in the aquatic environment, selenium rapidly bio-accumulates in food chains, reaching levels that are toxic to aquatic life [23]. Impacts of selenium from coal mining can be seen in fishes resulting in severe growth deformities and complete reproductive failure [23]. Furthermore selenium exerts two main types of effects on fish: (a) direct toxicity to juveniles and adults, and (b) reproductive impacts from selenium that is passed from parents to offspring in eggs [23]. Type-a toxicity involves changes in physiology that causes damage to gills and internal organs, ultimately resulting in death of the fish [24]. If concentrations are high enough, some fish may appear swollen from accumulation of fluid (Oedema) or have cloudy lenses (Cataracts) in their eyes [25]. A variety of developmental abnormalities can result in newly hatched larval fish due to Type-b toxicity resulting in teratogenic deformities of the spine, head, and fins [26]. Chemicals released from the coal mines also contain high concentration of metals such as Cu, Cd, Fe, Hg and Zn, which also affect the organisms adversely [15].

Treated effluents from underground mines and runoff through valley fills elevate aqueous solute concentrations in downstream ecosystems [27]. Some of these solutes such as Se, Mg^{2+}, K^{+}, HCO^{3-} and $SO4^{2-}$ are directly toxic to biota of the river. In addition, elevated $SO4^{2-}$ also leads to increased production of bisulfide (HS^{-}), which is toxic to aquatic macro fauna and macrophytes, and promotes eutrophication, reducing oxygen availability for aquatic fauna. Increased bulk ionic concentrations in stream water may negatively affect aquatic biota by disrupting osmoregulation [28]. Some common impact of coal mine activities include, low dissolved oxygen, higher sulphate content and turbidity which affect the aquatic life and reduce fish diversity to a great extent [29]. Gills of fish have an important role to play in gaseous exchange, osmoregulation, acid base balance and excretion of nitrogenous compound [30]. Water quality changes causes tremendous stress to the fish in carrying out its respiratory and other functions which results in distortion, epidermal detachment, fusion of gills and necrosis of rackers etc, [31]. Fish that are exposed to water with low pH show significant damage in gills including lifting, sloughing, necrosis of the branchial epithelium and shortening of tight junctions between cells of branchial epithelium [32].

The primary cause of death of fish residing in acidic waters is loss of sodium ions from the blood. Low availability of oxygen in cells and tissues leads to anoxia and ultimately death as acid water increases the permeability of fish gills to water [33]. Low pH though is not lethal directly but may adversely affect fish growth rates and reproduction [34]. Water pH was below 4.5 in most of the rivers in Jaintia Hills as reported by Swer *&* Singh, [18]. This was most likely responsible for complete elimination of fish from the natural waters of the area.

3.3 Case study of Fish Toxicity Due to Coal Mining

Studies on water bodies surveyed around Jaintia Hills of Meghalaya by Mylliemngap & Ramanujam in 201 [29] showed complete absence of fish fauna in the coal mining areas. "It has been reported that a total of 24 species of diatoms belonging to Bacillariophyceae and a few species belonging to Chlorophyceae were recorded from AMD impacted streams as compared to 56 species from unimpacted stream" [35]. Absence of such species may be one of the causes for less food and oxygen availability for fish residing in water bodies containing huge amount of AMD. Dissolved heavy metals commonly found in waters polluted by acid mine drainage are toxic to the aquatic biota (Ali et al.*,* 2002 [36]; Sprague, 1964 [37]). The toxic effects of heavy metals have tremendous impact on the physiological and biochemical processes in body system of fish [38]. "In a study conducted by Lakra et al., [10], histopathological changes were observed in tissues of the catfish *Clarias batrachus* reared in a pond receiving effluent from coal mine. Reports indicated that the levels of heavy metals like Fe, Zn, Mn, Cu, Ni, Cd, Pb, and Cr were higher in different tissues of the fish". Fe and Zn were reported to be accumulated in large amount in the liver and kidney. "Metal accumulation in muscle tissue of *Schizothorax plagiostomus* have been reported by Ali and Khan [7] which was collected from the metal-contaminated rivers of Pakistan".

The reports of Talukdar et al., [39] conducted in Simsang River, Garo Hills of Meghalaya indicated that the fish species in the adjacent areas of the coal mining sites were not evenly distributed. They reported that coal mining activities has a strong impact on water quality and fish diversity of the Simsang River as evident from low pH, DO, sulphate concentration and least diversity indices. Dissolved heavy metals are toxic to the aquatic biota containing huge amount of acid mine drainage [40].

The aquatic biota of Simsang river, which is the longest river of Garo Hills, Meghalaya has been facing serious threats due to haphazard coal mining activities. Two main reasons were responsible for hazards to the biota of the river; a) coal mine activities drains acid mine drainage (AMD) directly into the river and b) dumping of coal for auction on its bank. Due to the practice of open cast coal mines in the region of Garo Hills, seasonally some areas of the river are devoid of any aquatic organism [14]. "Common impact of coal mine activities include, low dissolved oxygen, higher sulphate content and turbidity which affect the aquatic life and reduce fish diversity to a great extent" [29]. "The primary cause of water quality degradation and the trend of biodiversity depletion in the water bodies of the coal mining areas are attributed mainly to the AMD, which makes water extremely acidic and loaded with heavy metal" [41].

Some of the major physiological effects on fish or major organs affected due to coal mine drainage toxicity as studied by different researchers as well as authors are described in details below:

Liver: "A study conducted by Talukdar et al., [14] on fishes inhabiting coal mining affected areas of Simsang River, Garohills, Meghalaya revealed disintegration of cell boundaries and slight dilation of blood sinusoids, damaged hepatic cells, swollen hepatocytes, lose connection between the cells and increase accumulation of pyknotic nuclei in liver of *Tor tor*. Similar pathological injuries were reported by Lakra et al., [10] in the liver of the CME-polluted pond water fish which include congestion of blood cells around the central vein, hepatocellular degeneration, and extensive fibrosis".

Kidney: "In the same study by Talukdar et al. [14] in fishes inhabiting coal mining affected areas of Simsang River, Garohills, Meghalaya, the changes in the kidney were observed as disturbed organization of Bowman's capsule and renal tubule such as shrinked renal tubules". They concluded that these changes observed were due to the highly acidic water resulting from coal mining activities (pH 3.6–4.8). Further when large quantities of rock containing sulphide minerals are excavated from an open pit in open cast mining it reacts with water and oxygen to create sulphuric acid. This acid is carried off by rainwater or surface drainage and deposited into Simsang Rivers. "Similar pathological injuries were observed by Lakra et al. [10] in the kidney of the CME-polluted pond water fish in which glomerular shrinkage with increased Bowman's space and hypertrophy of epithelial cells of the renal tubules with consequent reduction in tubular lumen occurred". "Similar hypertrophy of epithelial cells was observed in the kidneys of another air-breathing teleost fish *Channa punctatus* which was exposed to hexavalent chromium. Changes occurred include reduction of tubule lumens, contraction of glomerulus with increase of space inside the Bowman's capsule, nuclear pyknosis of epithelial cells, and increased space between the inter-renal cells" [42].

DNA Damage: "In another study conducted by Talukdar et al. [43] in fishes found in coal mining affected areas of Simsang River, Garohills, Meghalaya, most frequent aberrations observed were decondensation. AMD induces single strand breaks that could possibly initiate double strand breaks that increase the possibility of DNA damage as a result of inactivation or alternation of repair mechanisms" [44]. Their findings suggested that the potency of genotoxicants in the river was at the maximum level in the monsoon. It may be due to flowing of AMD mixed water from nearby coal field present in the river bank which was reflected by the genotoxicity test. These tests were performed using *Channa punctata* as a model fish collected from the affected mining area.

RBC and HB count: "In a study conducted by Talukdar et al. in 2017 [9] on cytotoxic and genotypic effect of acid mine drainage on *Channa punctata*, observed that after exposure to AMD the RBC count and Hb content decreased than the normal level". It was also observed that the decrease in total erythrocyte count may be attributed to the toxic pollutant present in the AMD. The toxicants in AMD contain a high amount of sulphate and these toxicants leads to the malfunctioning of the haemopoietic system of fishes. As a result the haemopoietic tissues fail to release the blood cells which are subsequently released into the blood stream.

Skin: "The skin of the fish maintained in toxic pond water showed severe toxicopathological alterations. Immediate responses of the skin against the toxic stress include hyperplasia and hypertrophy of the goblet mucous cells" [45]. "The club cells present in bronchioles exhibit extensive physical changes including shrinkage and swelling of their cytoplasmic contents which leads to loss of their typical club cell like configuration. These physical damages might denude the body surface leading to exposure of the underlying edible muscular components of the fish" (Chandra & Banerjee, 2003 [46]; Kumar & Banerjee, 2012 [47]).

Gills: "The gills of fish raised in the toxic pond water also showed severe histopathological alterations including detachment of the epithelial lining of the secondary lamella (SL) from their underlying ladder-like pillar cells and blood channel system. Further, the epithelial lining of the SL showed hyperplasia which led to increased blood dissolved oxygen barrier distance causing impaired respiratory activity of these fish" [45]. "Extensive wear and tear with detachment of the respiratory epithelia of the secondary lamellae from the basement membrane along with increased width of the respiratory lamellae were also reported by" Chandra & Banerjee [48].

4. CONCLUSION

The unscientific mining methods and strategies followed in the Garo, Khasi and Jaintia Hills of Meghalaya, North East India bring a severe threat to the icthyofaunal of the aquatic habitats in these regions. Acid mine drainage from the coal mines along with other anthropogenic activities have greatly led to the decline of fish diversity in the district. Some of the factors such as low pH, high metal content in the water bodies of the coal mining areas due to significant effluent from coal mines have resulted in the decrease of fish and other aquatic organisms. This study highlights 12 such areas in the Jaintia Hills, 10 areas in Khasi Hills, 4 areas in Garo Hills particularly the areas around Simsang River of Garo Hills that is undergoing extensive coal mining activity and the rivers/streams around these sites are highly polluted due to AMD of coal mines and is gradually becoming unsuitable for fish and other aquatic biota. This review will act as a guide book which will help to know the extent of effects of coal mining and to protect fish in other areas of India as well as world. Moreover this paper will act as an appeal for safety of the people that consume fish in these regions.

DATA AVAILABILITY STATEMENT

All data generated in the present study are included in the manuscript and its figures, tables and supplementary files.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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