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Environmental Footprints and Occupational Hazards of Clay Mining – A Case Study from Patel Nagar, Birbhum, West Bengal, India

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ABSTRACT

Mining is one of the main economic activities of any developing country. Pressure among mining and conservation is anticipated to escalate with the growing human population and technological advancement. However, mining has both negative and positive impacts on the environment as well as on society. During mine establishment and exploitation, habitat destruction is a part of all mining activities. Clay mining has major effects on the health of local people and causes the environment to break down. Both economically and ecologically, the china clay mines of Patel Nagar in Birbhum district hold a governing position. Both geomorphological processes and environments are affected due to china clay mining. Patel Nagar and the places around have a lot of good farmlands, which suffer the adverse effects of clay mining. Hydrological cycles are getting polluted along with the degradation of landforms, soot in the air, water and noise contamination, soil corrosion, and effects on natural drainage systems in the studied area. The majority of the local poor tribal people who work in mines also have certain health-related issues as an integral part of their occupational hazards.

Keywords: *Clay Mining, Environmental Degradation, Defaced Landform, Agriculture Land Reduction, Occupational Hazards.*

1. Introduction

Since the 16th century, clay has drawn scientists and technicians from a variety of fields. Clay is defined differently by scientists to suit their individual needs. The term “clay” was once used by sedimentologists to refer to particles less than 1/256 mm. Some sheet silicate minerals were first referred to as “clay” by mineral scientists. A dusty substance with some inherent mechanical strength is what clay is to an engineer (please correct this sentence). Therefore, it was necessary to provide a constant and widely accepted definition for clay and related materials in order to clear up this enigma and doubt. Thus, in 1995, the Clay Minerals Society (CMS) and the International Association for the Study of Clays (AIPEA) established the Joint Nomenclature Committee, which provided a consistent and generally accepted definition of clay.

The name “clay” refers to a naturally occurring substance predominantly made up of fine-grained minerals. At the proper water content, clay is typically flexible but will harden when dried or burnt [1, 2]. Kaolin/China clay, bentonite, bleaching earth, common clay, ball clay, fire clay, and refractory clay are the materials which are fulfilling all the conditions stated in the above definition. China clay, also known as kaolin, is made up of about 85% kaolinite [$Al_2Si_2O_5(OH)_4$]. It forms due to the weathering and thermal alteration of the mother rock, the precursor of clay, under favorable conditions. And mother rocks, in this case, are feldspars, muscovite, and other Al-rich silicates of acid igneous rocks like granite, rhyolite, quartz, diorite, etc. China clay also typically contains small amounts of mica, feldspar, illite, and quartz. Because of its favorable physical, mineralogical, and chemical characteristics, Kaolin is significantly used in manufacturing ceramics, cement, paints, refractory bricks, tiles, papers, drugs, toothpaste, fabrics, rubbers, and plastics [3]. They are also universally used as raw materials for building and construction because kaolin-made bricks are cheap, easy to produce, and have good geotechnical properties [4, 5].

Along the long path of civilization, humans stopped hunting for food as soon as they learned to use clay. Since the Stone Age, clays and clay minerals have been mined. Clays and clay minerals are one of the most important minerals used in manufacturing and the environmental field. So after the Stone Age, the clay age started. They used clay for home building, home decorations, and home utensils [6]. It has been confirmed from the archaeological excavation that man had used bricks to build houses from clay. During Harappa and Mohenjo-Daro civilizations from the Indus River Valley, human-used clay for different purposes [7]. With the expansion of civilization, increased use of clays in the industrial sector and their substitution for metals become infallible. Deposits of china clay are found in several locations around the Mohammad Bazar block. These resources are both sizable and profitable commercially. In this region, the qualities and grades of these clays vary from location to location as shown in Fig. 1. Kaolinite from various locations was evaluated by the Central Glass and Ceramic Institute (CGCRI), along with the research region, i.e., Patel Nagar, and was found to be advantageous for the ceramics industry. We will now focus our research on the Patel Nagar neighborhood in the Mohammad Bazar block of the Birbhum district.

Major economic activity which contributes significantly to the economy of India is the mining industry. It provides significant numbers of job opportunities. But environmental problems are created due to the mining. And, kaolin mining is no exception. Chemical and physical, these two types of environmental degradations are created due to kaolin mining and its beneficiation. Industrial applications of clay and its by-products are numerous and diverse. The acceptability of clay in a particular manufacturing unit depends on the properties of the clay. For the production of high-end

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porcelain, kaolinite-rich clay is majorly used. It is also used in the rubber industry because of its high surface affinity and very fine grain size. For the filling and coating of paper, clay is also used in the paper industry. It improves the appearance of the paper.

Fig. 1: Various types of clays in the study area. Red-colored, ferruginous clay is marked by the black arrow.

Clay minerals can also be used as filters and absorbents because of their cation property of some clay minerals. For this reason, bentonite clays are used as lubricating agents in drilling fluids. Therefore, clay can be used as an adsorbent, de-coloration agent, ion exchange, and molecular sieve catalyst [8].

Fig. 2: Water infiltrated the china clay quarry at Patel Nagar, especially during rainy sessions and discharged water after the beneficiation of clay.

Water and different types of chemicals are used during the beneficiation of kaolin, as a result, the water becomes contaminated and is discharged after the beneficiation. If we discharged these contaminated waters to the fields, then it will affect the crops. Water discharged from mines also creates problems for crops. Moreover, for human consumption, this contaminated water is hazardous (Fig. 2).

2 Geology of the Area

2.1 Regional Geology

The Archean rocks, consisting of granites, granite gneiss, biotite-schists, and calc-granulites are exposed in the South-West and North-West side of the Birbhum district and forms the basement of the Rajmahal Basin. Among these rocks, gneiss is predominant and intruded in the pre-existing schists. The Rajmahal Basin hosts undifferentiated Lower Gondwana sediments followed by Upper Triassic Dubrajpur and Middle Jurassic to Lower Cretaceous Rajmahal Formation [9]. In the southeastern part of the Basin, the Dubrajpur Formation unconformably overlies the Archean rocks. The lithology of the Dubrajpur Formation is gritty and ferruginous sandstone and shaly clay. Well-preserved fossil plant impressions indicate the Upper Gondwana age. Rajmahal Formation is the uppermost unit of the Gondwana Supergroup and comprises mostly of fine to coarse-grained basalts consisting of pyroxenes and plagioclase feldspars with ophitic textures. Basaltic lava was emplaced either on the Upper Triassic Dubrajpur Formation or on the Lower Gondwana sediments. Rajmahal trap achieves a thickness of about 330 m. Towards the south, near the eastern part of Raniganj Coalfield, the thickness of Rajmahal traps was reduced to about 100 m. The intertrappean sediments show variation in thickness from 1 to 26 m [10].

Cenozoic sediments overlie the Gondwana sediments patchily and are exposed near Patel Nagar Mokdamnagar-Mohammad Bazar area, Chaknurai, and Chaubatta areas. This Tertiary succession is comprised mainly of clays and sandstones, overlying the Rajmahal traps on the Northern side as in Chaubatta [11]. In the South near Adda, the basement rock of the Archean age gets exposed. The study area is mainly underlain by the Archean basement rocks and Rajmahal traps. A generalized succession of the region is given in Table 1 [12].

Table 1. Generalized Stratigraphic Sequence of Birbhum District [12]

Age	Formation	Lithology
Recent	Alluvium	Loose soil, silt & clay
Quaternary / Tertiary	Undifferentiated Surficial deposits	Laterites, lateritic soil, lateritic gravel with petrified wood & china clay
	Unconformity	
Middle Jurassic to Lower Cretaceous	Rajmahal Traps and Intertrappeans	Flows of basalt and intertrapeans Sediments (Sandstone, shale, etc.).
	Unconformity	
Lower Jurassic (Upper Triassic)	Dubrajpur	Conglomerates, coarse to medium-grained sandstone, grey siltstone, mottled shale & thin coal bands.
	Unconformity	
Lower Permian	Barakar	Coarse to medium-grained sandstone, carbonaceous sandstone with grey shale, fire clay, carbonaceous shale, and coal seam.
Upper carboniferous to Lower Permian (Permocaboniferous)	Talchir	Greenish sandstone, siltstone, tillite, olive green shale
	Unconformity	
Precambrian	Metamorphics	Granites and granitoid, gneiss, pegmatite, quartz veins, and metabaic dykes

2.2 *Local Geology*

Sediments deposited in the western part of Birbhum district are mostly alluvium in disseminated hillocks. The subsurface geological succession found in these areas is given below Table 2.

Table 2. Local Geological Succession of the Study Area

Recent	Alluvium
	Laterites and lateritic gravels with fossil wood
Tertiary	Clay beds
	Ferruginous and telepathic sandstones end clay beds
Middle Jurassic	Traps (Rajmahal)
Lower Jurassic (Upper Gondwana)	Flaggy Shales, clays, and compact sandstones (Dubrajpur Beds)
Unconformity	
Archaean	Granitegneisses, biotite-schists, cale-granulites with quartz and pegmatite veins.

Sedimentary rocks of the Dubrajpur formation unconformably overlie the Archean basements, towards the southeastern part of the studied area. Following Rajmahal traps are of Middle Jurassic in age. The unconformably overlying Tertiary succession of this area consists of mainly sandstone and clay along with some loose and friable sand and grit. These Tertiary clay beds occurred as thick beds forming the economic deposits of the district. The minimum thickness of these clay beds is about 30 m [13]. Though the Tertiary sediments mainly overlie the Rajmahal Traps, locally they overlie even the Archean basement also, especially towards the west and south of Makhdumnagar [13].

Vesicular-type laterites occur as a cap rock over the basalt and Tertiary sediments all over the study area. But the platy laterite varieties are found as a patchy deposit. Lateritic gravel of detrital nature occurs extensively. Few loose fragments of silicified wood fossils were found in these clay beds as well as in the Tertiary sediments.

3. Results and Discussion

Various types of reactions are occurring in the environment. Some of these reactions contribute to environmental pollution. These are energizing processes, whereas some reactions are generating resistance to environmental pollution. These are reactions that neutralize environmental pollution. Regardless of the surface conditions of the planet, clay remains stable. Therefore, they are not stimulating any reactions. Rather can assist us by eliminating contaminants and pollutants from the solution. As it is extracted, commonly with the open-cast mining process, the basic environmental balance in and around the mining area gets disturbed. The environmental impacts depend on mining policy, hydrology of the area, climatic conditions, rock types of the area, size of operation, landscape, and many other reciprocal factors [14].

To get a diversified idea about the negative impacts of china clay on the environment, we have to understand the following two ideas separately:

a) During mining activities, the environment may be degrading. Beneficiation activities of the china clay also affect the environment.

   China clay may present with other economic materials in the host rock, country rock, or even the overburdened material of those economic deposits. So during the mining activity of those economic deposits, the environment may degrade due to clay. Even the clays of dumping yards, building sites, or manufacturing sites have negative impacts on the environment.

Open-cast mining has different stages. First of all, before starting mining, miners have to excavate and remove the vegetation, soil, and overburden from the mining area. During excavation, they also have to dispose of the waste materials in a proper place so that these waste disposals cannot create any further environmental degradation. During the beneficiation of china clay, impurities are removed to give the clay the desired form.

Each stage of these mining processes has different negative impacts on the environment. Due to the stripping of overburden, the top of the mine area has to remove along with a large amount of vegetation. Surrounding environments are affected by the removal of vegetation. Part of the aquifer may also be affected while extracting clay from the mining area, especially during deeper mining. Due to the evaporation of water from the exposed aquifer, there will be a loss of groundwater. It will affect groundwater circulation. As the aquifer is exposed, so it also increases the chances of groundwater pollution [15]. Even shallow mines also can stop the runoff and interflow. As a result, water wastage is increasing and scarcity of water is also expanding within the surface water bodies of the area [16]. It will destroy more vegetation and topsoil in an area when we dump the mine waste in that area. Moreover, harmful chemicals containing dump waste will release pollutants into water, especially during rainy seasons (Fig. 3). This leached-out water will pollute the sub-surface water and surface water bodies of the surrounding areas.

With no exception in Patel Nagar, Birbhum, kaolin mining activity is also creating problems for the environment. During the beneficiation of kaolin, a huge amount of water is discharged from the clay plant. This water is mostly contaminated. Hence, it will pollute the whole area wherever it is released. Land degradation is another problem due to the opening of kaolin mining in the study area. Besides this, extracted materials have to store or dump in an area. For this, land area is also used, and due to contact with the clay, the area may degrade. For achieving china clay, sometimes the topsoil has to be removed from the proposed mine area. This removed soil is again dumped in another place and thus land of the area is degraded. The abandoned mine site is another problem. Thus, it must be filled with some other materials like sand and soil. Due to solid waste disposal, the environment is also degrading in the study area as shown in Fig. 2. Moreover, deforestation will account for the drastic change in atmospheric conditions. Deforestation accounts for 27% of the total added global warming potential in India. To establish mine, especially in the forest, requires deforestation. Apart from this, there will be no plants or cultivation in the mine area as long as the mining will continue.

Fig. 3: Mined Clay locally stored in the dump yard, immediately after the mining and later on transported the raw clay to the factory for further processes.

Open cast mining is done by using different types of equipment like draglines, power shovels, front-end loaders, backhoes, scraper-loaders, and shale planers [17]. Operations of this equipment will create noise. The unwanted noise will affect the health of mine workers.

Dust is produced during carrying out the mining operations. Most of the China clay mines are open-cast in Patel Nagar. Though the dust produced by mining activity itself is of low amount, a huge amount of dust is being produced due to the transportation of clay and overburdened materials. Subsequently, the environment is affected due to this dust.

Kaolin occurs widely in ambient air as it is a natural component of soil [14]. Due to the mining and refining of kaolin, the locals are considerably exposed to kaolin. They are also significantly exposed to kaolin during paper, rubber, and plastic production, as kaolin is one of the raw materials for these industries.

As a part of occupational hazards, laborers of kaolin mines often develop radiologically diagnosed pneumoconiosis as they expose to kaolin for a longer time [18, 19]. With the help of prominent radiological investigation, declining lung function and deterioration of respiratory function, and allied symptoms are identified. Quartz is one of the compositions of kaolin. That is why miners are often affected by silicosis and lung cancer [19, 20, 21]. It has been reported that, due to exposure to quartz, there are significant increases in the incidence of or mortality from chronic bronchitis and pulmonary emphysema among the miners of Patel Nagar. IARC (International Agency for Cancer Research) [22] categorizes inhaled crystalline silica, such as quartz or cristobalite, as a Group-1 carcinogen. Silicosis is the most important effect for hazard identification and exposure–response evaluation (Fig. 4). Again it may lead to mild pneumoconiosis, known as kaolinosis due to long-term exposure to kaolin [19, 23-25].

In Patel Nagar, china clay of a white hue is extracted via open-pit mining. Therefore, when sunlight strikes mined china clay, it reflects the light and creates a scintillating effect on the eye. As a consequence of this ophthalmic issue, the mine worker's vision is impaired [26].

Fig. 4: Deploying indigenous labor for the clay slurry beneficiation process.

4. Conclusion

Similar to many other human activities, clay mining has a substantial impact on the environment. The effects of clay mining include soil erosion, air and water contamination, geo-environmental catastrophes, biodiversity loss, and economic loss. A similar trend has been observed in and around the Patel Nagar clay extraction sites. The local people suffer from different orders of ailments arising from their exposure to kaolin. The effect on the groundwater circulation system and agriculture is also detrimental. Proper mitigative measures should be taken to nullify such hazards. Rapid population growth, urbanization, and associated industrial development are the causes of unchecked mining, the emergence of new industries, and countless construction projects in various regions of the globe. Each of these generates massive amounts of waste, as well as toxins and contaminants. These pollutants are the greatest threat to the earth's surface. Researchers from all across the world are attempting to identify cost-effective methods for preventing waste-related environmental pollution and contamination. Due to the unique characteristics of clay, it can be used to address waste-related environmental issues. Therefore, concurrent investigation into the origin and nature of the clay is also required.

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