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A review: Land Degradation Due to Coal Mining, its Effect on Ground and Surface Water and its Reclamation of Mine Spoils in Singrauli Coalfields.

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Abstract: *In India, 147Mha of soil is estimated that has been degraded due to both natural and anthropogenic causes. Mining of coal has always been one such activity that requires the area to be dug out which results in loss of the productive soil in the region. The effect of mining is not just limited to land degradation, but it also has its impact on the surface and groundwater in the region. The water in this region was found to be contaminated with heavy metals and other parameters were also studied. This paper will help to see the change in land use/ land cover in the Singrauli coalfield and its surrounding areas due to opencast mining and also help to see the impact of mining on the water in this region. When the coal is mined, mine spoils or overburdens are formed near the periphery of these mines to store the soil and other materials that are dugout. Here we also discuss the biological and chemical properties of these overburdens. Overburdens over the years, as their age increases, vegetation seems to grow back on them and different studies were done to find the reclamation or restoration of these overburdens to restore the ecological balance in the region.*

Keywords: **land degradation, coal mine, heavy metal, reclamation, overburden, land use/land cover, surface water and groundwater**

Introduction

Land degradation is a process whereby the land is affected negatively by loss of fertility, loss of flora and fauna, and decrease in productivity caused due to human interference and environmental factors (Adamo and Crews-Meyer, 2006). These changes are undesirable and can often take decades to restore to their normal condition. This process has accelerated in the last 10 years and is a major concern worldwide (Ellis and Ramankutty, 2008). According to the UNCCD report of 2017, about 20% of the global vegetation cover has deteriorated in 15 years, this has caused a decrease in the production of vegetation (UNCCD, 2017). About 1964.4 Mha are degraded by human activity in the world (Dwivedi, 2002).

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India has only about 2.4% that is about 328.7 Mha of the total land in the world and accounts for 18% of the world's population (Bhattacharyya et al., 2015). This is a serious issue because the land degradation is about 147 Mha which includes degradation due to erosion (water and wind) and due to problematic soils and other environmental factors as well (NBSS and LUP, 2004). Not only this but human activities such as deforestation, mining, grazing, industrial development, etc have also accelerated degradation (Bhattacharyya et al., 2015).

Opencast mining of minerals affects the chemical, biological and physical characters of soil and has deleterious effects on the regions. Mining results in a decrease in the water table, contamination in soil, production of acid from the mine and causes pollution. These opencast mining produce overburdens/spoils which results in loss of topsoil and flora and fauna (Sahu and Dash, 2011). Overburdens are created by blasting the mines and then stacking the soil on top of each other to create mounds that are generally barren and have lost the ability to support vegetation (Anon, 2006).

The mining of coal in India alone has affected the land most in terms of area. Production of 407 Mt of coal creates 1493 Mt of overburden and affects about 10175 ha of land. A huge amount of mineral residue is left behind in addition to an enormous amount of degraded land. (Sahu and Dash, 2011).

India's energy capital, Singrauli, is home to one of the country's most valuable coalfields given deposits and production. Large-scale mining operations have created an enormous amount of stress on both land and ecology in this area (Greenpeace 2011; Singh *et al*. 1997). The area has been designated as an environmentally sensitive zone due to exploitation for groundwater, surface water, building materials, coal, and hazardous industrial waste dumping (Singh e*t al*. 2003). The coalfield occupies a land area of 2201 km^2, but only 300 km^2 is currently exploited for coal (Javed and Khan, 2012).

Change in land cover/land use in mining areas of Singrauli

For the three-time periods, spatial imagery from the Landsat series, IRS LISS II, and IRS LISS-III was used to analyze land-use change (Javed and Khan, 2012; Areendran et al., 2013). Landsat series satellites were used to map the land in 1991, IRS LISS II was used to measure data in 2001, and LISS III was used to measure the change in 2010.

Higher ridge areas were found to be mostly coated with dense forests or open forests, while low-lying areas had scrubland. Farmland and fallow land predominated in the plains and lowlands. It can be seen that the area under dense forest decreased between 1991 and 2010 but the scrubland saw an increase in the area during 1991 and diminished by the year 2010 (Javed and Khan, 2012). This decrease in the dense forest is because most coal reserves are located beneath the dense forest, the majority of coal mining takes place in dense forest areas. The open forest area has seen an increase in area from 2001 to 2010 and this is because the dense forest density has decreased but the reclamation of mine spoil has increased (Javed and Khan, 2012).

The area for Cultivated land has decreased in the period from 2001 to 2010 due to the development of thermal power plants, infrastructure, and residential complexes. The decrease in agriculture is due to lack of irrigation and dependence on rainfall which has declined too (Javed and Khan, 2012). This decrease in cultivated land has led to an increase in Uncultivated land. The water body has also seen a

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decrease in the area due to lack of rainfall, pollution, and siltation due to run-off that comes from the dumpsites.

The area in Mining has increased over the years and also the Overburden dumps area has also seen an increase due to mining where a huge amount of soil and other materials were removed and aligned in the nearby areas. The phase of urbanization accelerated throughout the 1980s and 1990s as the coal mining and power industries (Singh et al. 1997) flourished in the region, resulting in substantial growth in built-up areas between 1991 and 2010.

There are Ash Ponds around the periphery of the Govind Ballabh Pant Sagar reservoir which is made so the fly ash can be disposed of which is generated by the thermal power plants in the region. This area has also seen a significant increase due to an increase in the electricity generation from the power plants (Javed and Khan, 2012).

Biological and Chemical Properties of Selected Overburdens

The overburdens selected are present in the Northern Coalfields Limited's opencast project (OCP) of Bina Extension is based in Singrauli Coalfields, which is split between Uttar Pradesh's Sonebhadra district and Madhya Pradesh's Singrauli district.

1. Biological Properties:

Variations in soil stratification decreased biotic diversity, and changes in the composition and functionality of habitats are the most significant environmental impacts of mining. These changes affect nutrient and water dynamics, as well as trophic interactions (Matson et al. 1997, Ghose 2004, and Almas 2004).

The current thesis compared the microbial properties of various aged overburdens witnessing eco-restoration to native forest soil. This could aid in determining the biological properties of various ages of overburden spoil and the feasibility of using artificial interventions to improve overburden properties for plant growth.

Sample preparation and collection

Specific overburden samples were obtained with a spade from ten different locations. The samples were carefully combined, and a composite sample of 500 g was taken from each site. This soil was air-dried and sieved at a scale of 2 mm. Forest region (S1), five-year-old overburden (S2), twelve-year-old overburden (S3), and sixteen-year-old overburden (S4) were among the overburden samples obtained (Pandey et al., 2016).

Biological Analysis of the sample

The samples were then used to figure out the following parameters: Microbial Population Counting, Enzymatic Activities, and Microbial Basal Respiration.

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Result of the Analysis

The population of bacteria, fungi, and actinomycetes was found to be greater in S1 followed by S4 overburdens. S2 had the least number of microbial colonies in it (Pandey et al., 2016).
Enzyme activity too was minimal in S2 due to decreased population of microbes. Enzyme activity was highest in the S1 region which can be credited to the fact that it had a more organic matter and supported more microbial population and activity (Pandey et al., 2016).
The rate of CO_2 evolution was high in S1 due to more organic matter in the soil and was least in S2.

2. **Chemical Properties:**

This was done to assess the chemical properties of OB (overburden) material deposited at the mine site and monitor changes in the dumps' chemical properties over time as the natural reclamation process unfolds (Verma et al,2016).

Sample collection and preparation

Samples were collected from the Forest land (NF), five-year-old overburden (S1), twelve-year-old overburden (S2), and sixteen-year-old overburden (S3). The samples were then mixed and a composite sample of 500g was used in the lab where it was first air-dried and then cleaned and crushed, then was sieved through a 2 mm mesh sieve (Verma et al,2016).

Chemical Analysis of the sample

Using the conductivity meter and pH meter, the electrical conductivity and pH of the suspension (water/soil 2.5:1) were determined respectively.
Using Walkley and Black's method, organic matter was determined (Walkley and Black, 1934).
The alkaline per magnate method was used to determine the available nitrogen (Subbiah and Asija, 1956). Other elements such as available phosphorus, available potassium, calcium, magnesium, and micronutrients (copper, zinc, iron, manganese, and nickel) were also determined.

Result of Analysis

The pH of the overburden samples ranged between 6 to 7.4. The NF had a neutral range of 7.4 whereas the S1 sample had 6.1. NF had a more organic matter to maintain the pH and the overburdens depending on their age had a different level of organic matter where S1 had the least which led to more acidic pH (Verma et al,2016).
The EC had a range of 0.07-0.30 dS/m. The variation can be accounted for by plant uptakes, leaching, and parent materials composition.
Nitrogen(N) was deficient, Potassium(K), and Phosphorus (P) in the overburden dumps (Verma et al,2016).
The presence of organic carbon in the overburden samples was very low, i.e., ranged between 0.11% – 0.34%, whereas NF had 0.67% of organic carbon in it(Verma et al,2016).

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The micronutrients such as nickel, manganese, and iron were found to be more in older overburdens, as the age of the overburden increased, the presence of these nutrients also increased (Verma et al,2016; Saviour and Stalin, 2012).

Effect of Mining on Surface and Groundwater

Coal mining is indeed a water-intensive operation that has resulted in groundwater reserves being depleted in some areas. Mining also has an impact on the environment (Rana et al., 2019).

Surface water quality

The samples were collected randomly from different areas and projects of the coalfields, NCL, and Singrauli district and in different seasons. The residential areas which were focused on consists of Amlori (1), Nigahi (2), Jayant (3), Dudhichua (4), and Khadia (5).

These samples were used to test the following parameters: pH, EC, total dissolved solids, Alkalinity, and Iron.

pH – The pH was found maximum at site 1 with mean pH of 8.56 and minimum at site 2 with a mean pH of 8.19. This data was based on the year 2017-18. The pH value was found out to be high when compared to the normal range and is harmful to humans, animals, and the environment (Rana et al., 2019).

EC (µS cm^{-1}) – The mean EC was found 0.86 µS cm^{-1} at site 1 which was the highest and 0.33 µS cm^{-1} at site 4 which was lowest in the year 2017-18. It was stated that the surface water in the mining area had a higher EC level and is not good for the health of people and the environment (Rana et. al,2019).

TDS (mg/l) – The mean TDS was found highest at site 5 at 2151.41 mg/l and the lowest was found the site 2 at 1863mg/l in the year 2017-18. Having TDS in water results in waterborne diseases which decreases the potability of the water and it can cause gastrointestinal problems in humans (Rana et. al,2019).

Alkalinity (mg/l) – The mean alkalinity was found maximum at site 5 at 112.83 mg/l and the minimum was found at site 1 at 102.25 mg/l in the year 2017-18. This increase in Alkalinity reduces the quality of water and its daily consumption can lead to health risks (Rana et. al,2019).

Iron(mg/l) – The mean iron level was found high at site 1 with a value of 1.61 mg/l and a low concentration at site 2 with a value of 1.29 mg/l in the year 2017-18. This level was slightly high than normal limits (Rana et. al,2019).

It was concluded that the parameters exceeded the normal range which was compared with CPCB (Central Pollution Control Board) and Bureau of Indian Standards (BIS). This inferred that the surface

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water if consumed untreated can cause serious health issues in humans and animals. It was also suggested to drink treated water and promote the plantation of trees and plants to decline the pollution level.

Groundwater quality

The groundwater samples were collected from hand pumps and wells in 1-liter polythene bottles, these samples were collected from 8 different stations present in the vicinity of the Coalfields. The water samples were collected at 2 different periods, i.e., pre-monsoon and post-monsoon season (Sonkar and Jamal, 2019).

These samples were used to assess the following parameters: pH, EC, TDS, and Dissolved Oxygen.

pH – The pH during pre-monsoon ranged between 7.18 - 7.98 and during post-monsoon it ranged between 6.85 - 7.34(Sonkar and Jamal, 2019).

TDS – The value of TDS for pre-monsoon ranged between 146 – 467mg/l and during the post-monsoon season it ranged from 109 – 382mg/l (Sonkar and Jamal, 2019).

EC- The EC was found 248-933 μS/cm during pre-monsoon season while it ranged 212-831 μS/cm during the post-monsoon season. This is a high range (Sonkar and Jamal, 2019).

Dissolved Oxygen (DO) – The value for pre-monsoon was 4.98-5.72 mg/l and for post-monsoon, it was 5.02-5.72 mg/l (Sonkar and Jamal, 2019).

It was concluded that groundwater in the area had an alkaline nature. The EC was also found to be above the permissible limit which was prescribed by the BIS in both seasons. It was recommended to treat the water before consumption to prevent health diseases (Sonkar and Jamal, 2019).

Presence of Heavy metals in water

Industrial discharges, mine operations, coal-based thermal power stations, fertilizers based on arsenic, and agricultural runoff are the major anthropogenic contributors of heavy metal emissions in water supplies (Singh and Kumar 2017; Sharma et al. 2007; Usham et al. 2018; Pandey et al. 2011; Chowdhury et al. 2016; Dubey et al. 2012). Since coal washery runoff contains heavy metals, it can contaminate the surface and groundwater (Finkelman 2007). The samples collected for testing of heavy metals in the water were taken from the areas surrounding Renukoot, Vindhyanagar, Anpara, Kakri Mines, Jayant mines, and Khadia mines. This was done in December of 2015. 50+ samples were collected from the region in which 27 samples were from the hand pump and represented groundwater; 21 samples for surface water were collected from various drains, ponds, and lake water (Bhardwaj et. al, 2020). Samples were sent to IIT Mandi labs and NABET labs, i.e., CEG test house which is in Jaipur for analysis of heavy metals.

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Result of analysis

Heavy metals like Hg, As, Cd, and Pb are present in alarmingly high concentrations in both field and surface water samples, with concentrations above the World Health Organization's permissible limit (WHO, 2011) in the majority of the samples. Almost all of the groundwater samples tested positive for Hg and As, making them unfit for consumption and domestic use (Bhardwaj et. al, 2020). The majority of the contaminated samples were found near thermal power stations, mines, and ash ponds. The ash ponds serve as a source of pollution, which seeps into the groundwater and in turn contaminates the hand pumps nearby.

Mine spoils' heavy metal toxicity prevents nutrient intake, plant growth, and microbial community (Chaubey et.al, 2012).

With the above result, it was concluded that there needs to be better regulation of water resources, monitoring, and purification of water (Bhardwaj et. al, 2020).

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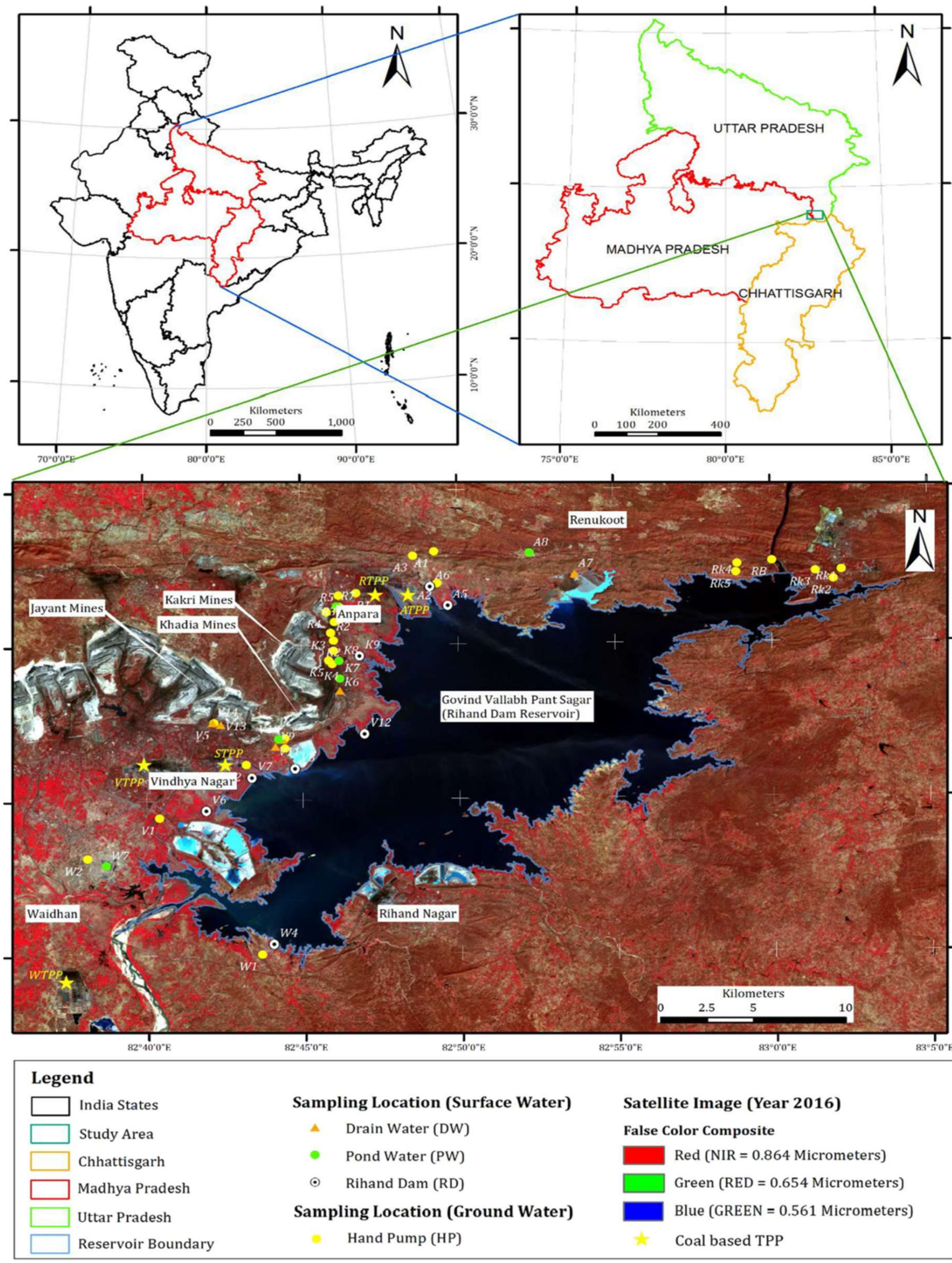

Figure 1 - Map of the study district, showing sampling positions near TPPs, coal mines, and the Rihand reservoir. ATPP: Anpara Thermal Power Plant; RTPP: Renusagar Thermal Power

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Plant; STPP: Shaktinagar Thermal Power Plant; VTPP: Vindhyachal Thermal Power Plant; WTPP: Waidhan Thermal Power Plant are the five TPPs in the study district. The size of the region is shown by a Landsat satellite image from 2016, which is shown using a regular false-color composite (FCC).

Reclamation of coalmine spoil

Fruit orchards Agroforestry and eco-restoration parks are the most common post-mining land uses in India. Mine-affected lands could also be used for agriculture by the local population (Ahirwal and Maiti, 2016).

To re-establish the features of an ecosystem, rehabilitation of degraded lands is critical. The majority of organic carbon and nitrogen is bounded to SOM. Mined land's surface has been exposed to a variety of biological and physicochemical changes, resulting in a massive depletion of SOM. The depletion of SOM due to mining operations has a major effect on the mine soil's fertility and nutrient dynamics. Re-establishment of leguminous plants, which increase the N reservoir, could be important for long-term restoration success (Kumari and Maiti, 2019).
MP Forest Development Corporation has been planting overburden areas in various years since 1990-91. Ornamental, timber, fruit-bearing, medicinal, and ecological qualities are all represented among the species planted here (Chaubey et.al, 2012).

On the coal mine spoils of the Singrauli coalfields, a total of 197 Angiosperms from 45 families including 146 genera were discovered. Herbs accounted for 113 (57.36 percent) of the overall species of plants registered, undershrub for 9 (4.56 percent), shrubs for 16 (8.12 percent), trees for 57 (28.93 percent), and woody grasses for just 2 (1.01 percent). The Fabaceae family dominated the spoil, accounting for 20.30 percent of all plant species (Singh,2011).

VAM was also used to study its impact on the reclamation of overburdens. VAM can grow within plant roots and have a variety of benefits. These fungi supply the nutrients and convert them into a shape that plants can use. Its ability to retain heavy metals while removing them from mine spoils and overburden soils in its cell wall has proven to be extremely useful in reclamation efforts (Chaubey et.al, 2012).

With all these findings it was concluded that the physicochemical properties of soil, such as water-holding capability, bulk density, electrical conductivity, pH, fertility status, organic matter, Calcium, and Sodium were found to improve steadily with the age of plantations as a result of rehabilitation practices. In terms of heavy metal concentrations, such as Zn, Cu, Mn, and Fe, it showed a declining pattern as the age of the plantations increased (Chaubey et.al, 2012). It was also found that Angiosperms are the only vascular flora found on the overburdens of the Singrauli coalfields. The herbaceous flora outnumbers the woody flora. The flora on Singrauli coalfields' coal mine spoils is dominated by the Fabaceae, Poaceae, and Asteraceae families (Singh,2011).

Conclusion

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As coal mining activity expanded rapidly in the Singrauli Field throughout 2001 to 2010, changes in land use/land cover occurred. The capability of remote sensing and GIS in LULC analysis this sort of research could assist with land-use management, resource planning, and environmental impact assessment. It is possible to formulate a potential solution, an operational solution, and implement formal policies with it. It will assist in the proper management of landscapes, thus creating sustainable development and reducing non-renewable resources.

Central Pollution Board limit guidelines (CPCB) Most of the groundwater is contaminated with Hg and inorganic arsenic, which makes it unsafe for consumption and irrigation. The majority of the contaminated samples are located near thermal power plants, mining sites, along with ash ponds. contamination flows into groundwater and seeps into the associated ash ponds as the population grows, regulation, monitoring, and proper treatment of the Singrauli water sources are required. There should be stringent guidelines and hefty fines for wastewater discharge into the environment.

These studies are valuable for creating action plans to combat water pollution due to heavy metals. Poaceae, Asteraceae, and Fabaceae are the dominant plant families on spoils of the Singrauli Coal Mine. An abundance of AM spores was found in older plantations. In younger plantations, AM spores were progressively depleting and could be detected fresh over a soil horizon. The biomass of the microbes was varied in soil samples.

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