Heavy Metal Accumulation in Rural Area of Dumka

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Abstract: Shikaripara is a well suitable place for vegetation and also a best place of mining. A huge amount of coal is located near shikaripara which is located near Dumka of Jharkhand State. Due to this, many were benefited. Besides there slowly rising of soil pollution which is greatly effecting the people, plants, animals. Here the heavy metals accumulated in the soil are tested using Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and its composition is also noted by this equipment. Finally, the level of pollution and Geo-accumulation Index is noted in the soil of Shikaripara region.

Keywords: ICP-MS, Heavy metals, Accumulation.

1. Introduction

Mining stones are used to develop infrastructure. These stones are used to construct building and roads. It can significantly boost the local community's socio-economic well-being through job creation, increased income, infrastructure development, and economic diversification. Nearly 19% of people are benefited directly with help of jobs in mining area. To extract these mines drilling is done to the rocks to create holes. The mining operations are being conducted in accordance with Rule 106 of the Mines and Minerals (Development and Regulation) Act, 1961 [1].This act governs the regulation and development of mines and minerals in India. This mining operation is safety and are legally permitted by Directorate General of Mines Safety (DGMS) is a government agency responsible for ensuring the safety, health, and welfare of people working in mines [2].

2. Experimental

Location: The mining for Kendpahari Stone Mine covers an area of 7.19 acres (2.91 hectares) in the Mouza–Kendpahari, Panchayat- Jhunki, Shikaripara, District–Dumka, State–Jharkhand, with the following geographical coordinates:

Latitude: 24°13'22.73"N to 24°13'15.84"N

Longitude: 87°38'00.59"E to 87°37'52.30"E

The primary mineral of interest in this mining operation is stone(Decorative/ Ornamental/ Stone chips), and the geological reserve of stone in this area is estimated to be 571,040 cubic meters. However, not all of this geological reserve is necessarily mineable. The mineable reserve, which is the portion of the geological reserve that can be economically extracted, is estimated to be 399,728 cubic meters. This means that the mining operation will focus on extracting approximately 399,728 cubic meters of stone from this site. It's important for the mining company to adhere to all relevant environmental regulations, safety standards, and community engagement practices during the mining process to ensure responsible and sustainable mining operations [3].

Figure 1: Location of Shikaripara inDumka, Jharkhand

Working in Mines: Mining involves drilling holes in rocks to extract stones and minerals used in construction. Proper septic tank and soak pit design and maintenance are crucial to prevent groundwater contamination. Regular inspection is essential for an effective wastewater treatment system. Sustainable waste management minimizes environmental impact in mining.

The mining method is semi-mechanized open-cast with a Shovel-Dumper combination [4]. Stones are extracted using drilling and blasting with compressed air wagon drills. Material is loaded into tractor/tippers and transported to a crusher for processing. Safety is maintained with a 45-degree bench slope. The operation adheres to MMR-1961 rules, operates from 8 AM to 5 PM during 300 working days annually, and may slow down during the monsoon period.

Soil Polluted Due to mining: Mining activities release heavy metals like lead, mercury, cadmium, and arsenic into the soil, which can accumulate and harm plants, animals, and humans. Soil conditions and chemical reactions affect how these metals behave, and they can enter the food chain, posing health and environmental risks. Proper waste management and soil remediation are crucial to address these concerns. [5].

Testing by using ICP-MS: The Inductively Coupled Plasma Mass Spectrometry (ICP-MS) technique is specifically applied to examine the amounts of heavy metals in samples taken from the mining region in order to investigate the buildup of heavy metals in the Shikaripara Stone Mines. It is essential to appropriately collect and prepare soil samples from Shikaripara.

Soil sample is gathered with a distance of 0.5m to 2.5km from mine near shikaripara. Nearly 1kg of sample is collected to a depth of 15cm and sealed inside the polythene bag safely. This soil is made to dry over 25^0C to 30^0Cto remove excess water in the soil and powdered as a fine particle [6]. Then coning and quartering method is used to reduce the impact of any heterogeneity in the original soil sample. Next a portion soil is taken in required quantity to find the variations in the soil. These fine particles are sent to ICP with a high temperature to ionize the particles using plasma. The high-energy environment of the plasma source breaks down the sample into its constituent elements. The ions generated in the ICP are then passed into the mass spectrometer. Inside the mass spectrometer, the ions are separated based on their mass-to-charge ratio. This separation allows for the identification of individual elements and isotopes.This information is used to determine the concentrations of the elements in the sample [7].

3. Result and Discussion

In the mining area of Shikaripara, heavy metal accumulation in soil begins with the exposure of heavy metal-containing ores and minerals during mining activities. This exposure triggers leaching, a chemical reaction in which water dissolves heavy metal ions from the minerals into the soil. Factors like soil pH and organic matter affect how these metals bind to soil particles. Some plants in the area can absorb heavy metals from the soil, potentially entering the food chain. These chemical processes influence the extent of heavy metal pollution and require careful assessment and mitigation efforts.

ICP-MS is used to determine the concentrations of various metals in the soil sample. It is an excellent technique for this purpose because it can detect a wide range of elements, including metals, at extremely low concentrations. This makes it valuable for environmental assessments, such as assessing soil pollution due to mining, as it can identify the presence and quantify the levels of potentially harmful metals like lead, mercury, cadmium, and others.

In an environment, protection to health is very important. In order to find the pollution level in the soil over shikaripara area, ICP-MS is used. By this each element weight is noted separately and is listed in below in table 1.

Table 1: Soil composition in mg/kg

Range	Lead (Pb)	Arsenic (As)	Mercury (Hg)	Cadmium (cd)	Iron (Fe)	Manganese (Mn)	Zinc (Zn)	Copper (Cu)
Actual	4.579	0.620	0.12	0.17	11067.46	436.18	10.945	2.430
Limit	5	4.5	0.05	0.1	1200	500	60	50

ICP-MS gives exact measurement of the values in the particles. Pb contains 4.579 mg/kg where it permitted till 5mg/kg. Increase of this may affect children and pregnant ladies with various health issues. As has 0.620mg/kg with little amount where it is permitted to 4.5. Mercury has 0.12mg/kg with high amount where it is permitted to 0.05. So care should be taken to control Hg otherwise it leads to respiratory issues. Cd has 0.17mg/kg where it is permitted to 0.1mg/kg. Small amount of Cd can cause great health issues. Iron has 11067.46mg/kg. This concentration can affect water quality and industries badly. Mn has 436.18mg/kg which is in the permitted range and safer. Zn has 10.945 also lays under the permitted level. Cu has 20430mg/kg which is in the permitted range of 50mg/kg.

Evaluation Techniques: Geo- accumulation Index is a factor to identify the level of pollution in the soil is formed with heavy metals. This is calculated by the formula given in equation 1 [8].

$$G = \log_2\left(\frac{T_m}{1.5H_m}\right) \quad (1)$$

G is the geo-accumulation index with logarithmic terms in ratio of concentration T_m of metals m to the reference value of historical geo-chemical value. For the considered region shikaripara region geo-accumulation value is -1.

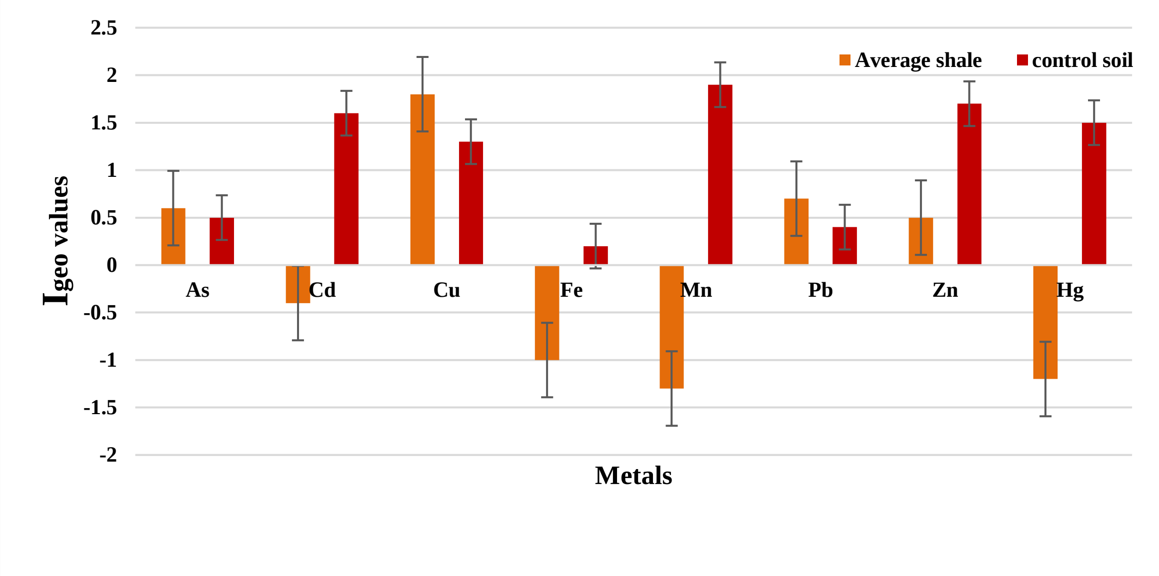


Figure 2: Comparing Geo-accumulation index in nearby regions of Dumka

Figure2 shows the comparative graph for the particles obtained from the soil of Dumka regions. This shows that soil needs be taken for to avoid such accumulation of heavy metals during mining process.

Pollution Index I is utilized to provide a complete measure of pollution by taking into account multiple metals present in the environment and expressed as shown in below equation 2.

$$I = \left(F_1 + F_2 + F_3 + \ldots\ldots\ldots\ldots + F_p\right)^{\frac{1}{p}} \quad (2)$$

If $I < 1$ then it is not polluted

$1 < I < 2$ then it is little bit polluted

$2 < I < 3$ then is polluted in medium level

$3 < I$ then it is polluted extremely

Concentration factor F with p different materials obtained through ICP-MS classification. In shikaripara region pollution load index is noted as 0.6. This shows that the pollution in the soil is very less over that particular region.

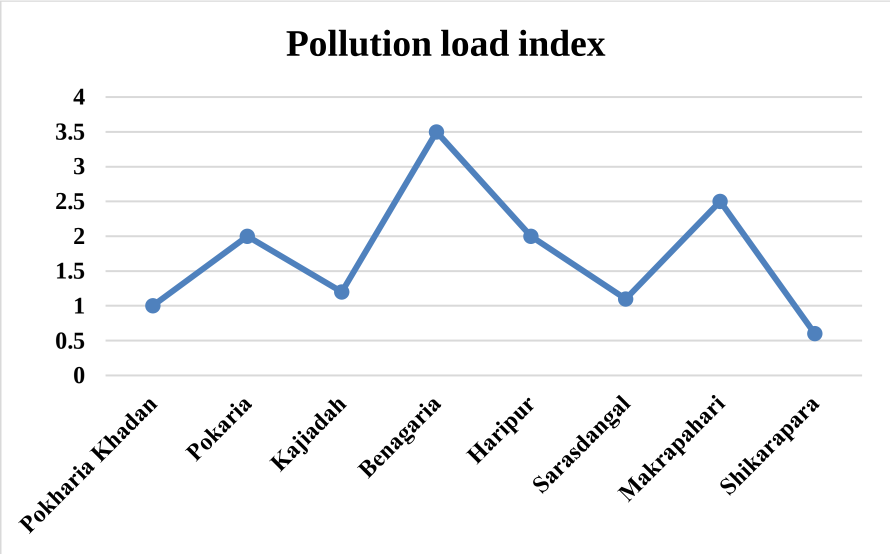


Figure 3: Pollution load index comparison over Dumka region

The load index for the pollution seen in the soil in graphically shown in figure 3. This tells that less quantity of 0.6 of index is affected in the shikaripara place. Where others were badly effected compared to shrikaripara place. Regulated measure should be taken to control the pollution in the soil.

Enrichment factor (EF)used to quantify the concentration of a specific element or compound in a sample relative to its concentration in a reference or background sample. This is given by below equation 3.

$$X = \frac{\left(\frac{K_n}{K_f}\right)}{\left(\frac{L_n}{L_f}\right)} \tag{3}$$

Concentration of element K_n to the concentration of the reference element K_f to the background element L_n to the background reference element L_f gives the enrichment factor X .

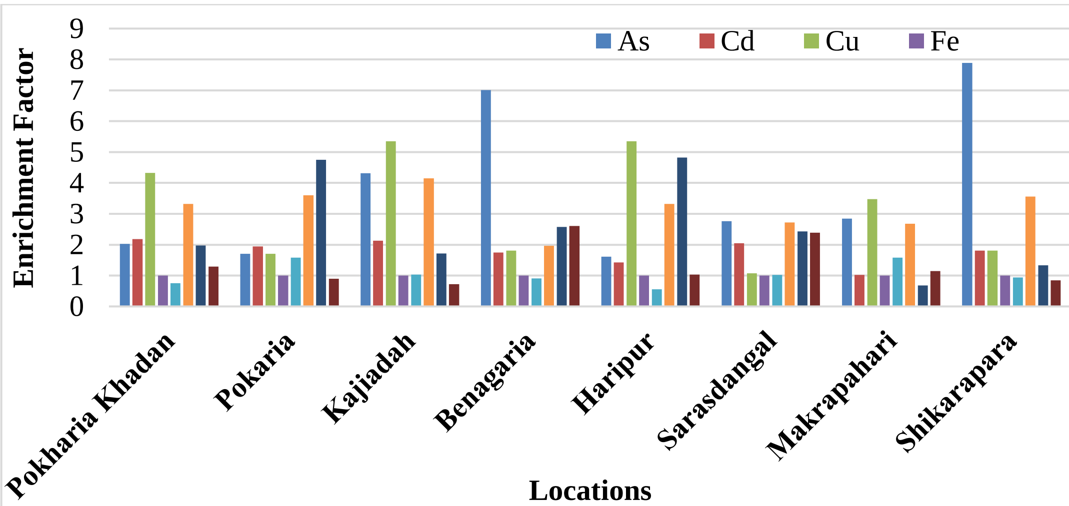


Figure 4: Enrichment Factor for Dumka region in Comparison

The comparative values of Enrichment factor for the place Dumka is shown in figure 4. It details all the elements present in the soil with their masses. The quantity of the enrichment is needed in order to find the pollution occurred in the soil.

Nemerow's Pollution Index (NPI) identifies primary water pollutants. The Nemerow Comprehensive Index assesses poor environmental conditions in agriculture lands near copper mining sites. It is given by below equation 4.

$$N_{PI} = \sqrt{\frac{p(X_d)^2 + (X_{fm}^i)^2}{2}} \quad (4)$$

Nemerow's N_{PI} is given by using Hakanson's modified degree of contamination index $p(X_d)^2$ and single pollution index X_{fm}^i.

if $N_{PI} < 1$ then it is uncontaminated;

if $1 \leq N_{PI} < 2$ then it is Minimal contamination;

if $2 \leq N_{PI} < 3$ then it is Moderately polluted;

if $3 \leq N_{PI} < 5$ then it is very polluted;

if $N_{PI} \geq 5$ then it is Severe contamination

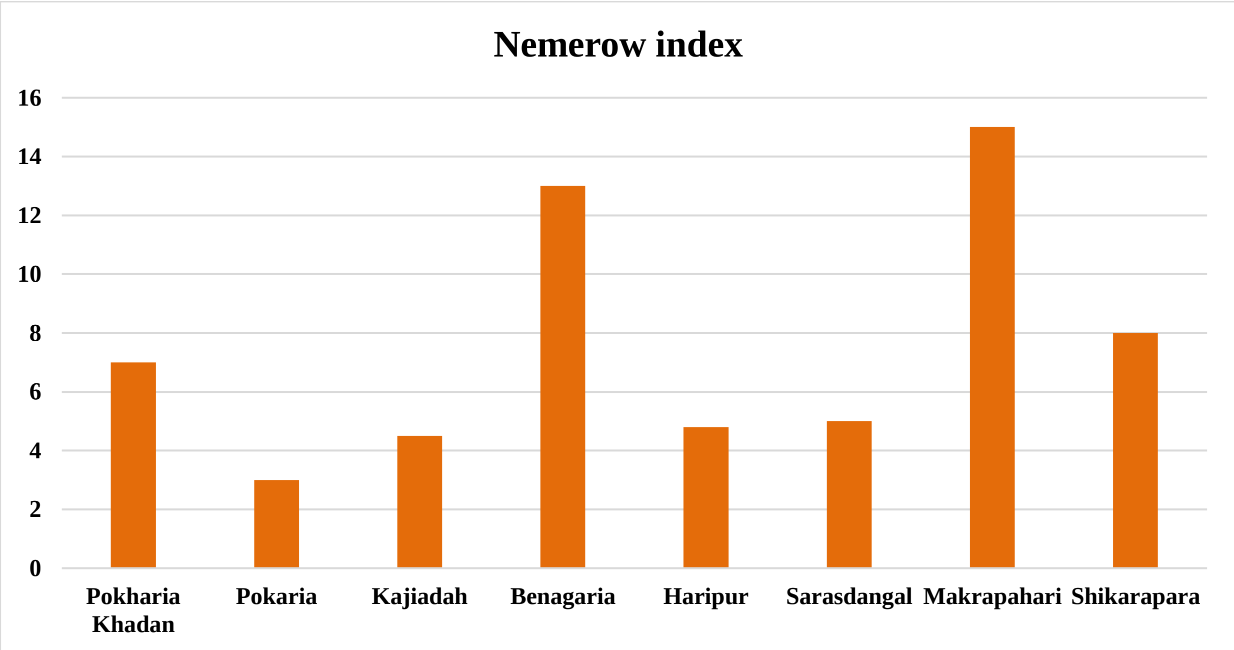
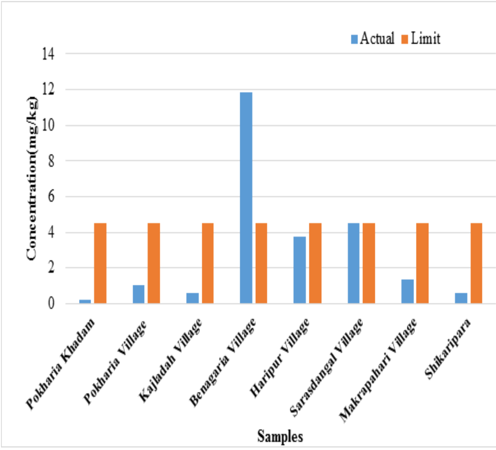


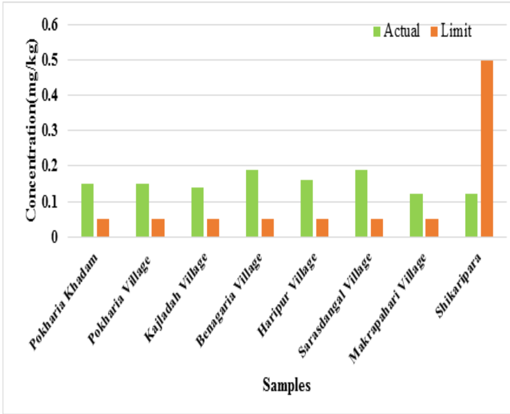
Figure 5: Nemerow's Pollution Index

Nemerow's Pollution Index of shikarapara in comparison with other regions are shown in figure 5. It is observed that shikarapara is having Nemerow's value of 5.

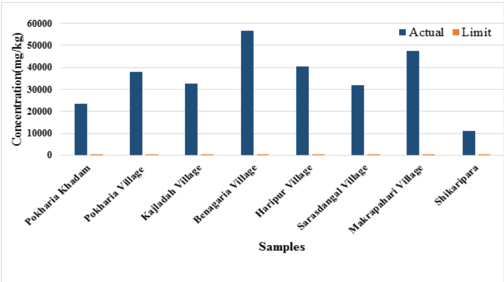
Comparison of Material values with other places: The obtained materials are compared with the materials obtained in other regions of Dumka which is near by places of Shikaripara. PokhariaKhadan, Pokaria, Kajladah, Benagaria, Haripur, Sarasdangal, Makrapahari are the nearby places of Shikaripara. The comparison of metals obtained were compared with this places and shown in figure 6.



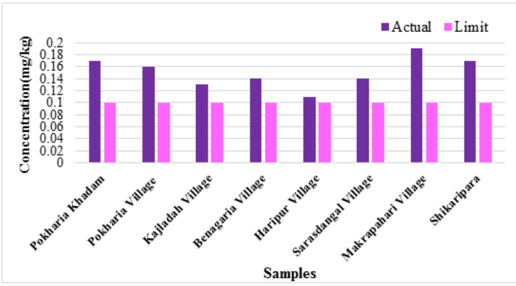
Concentration of Arsenic



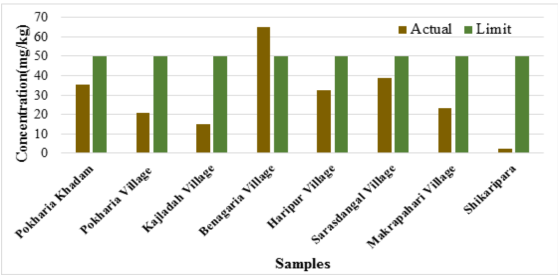
Concentration of mercury



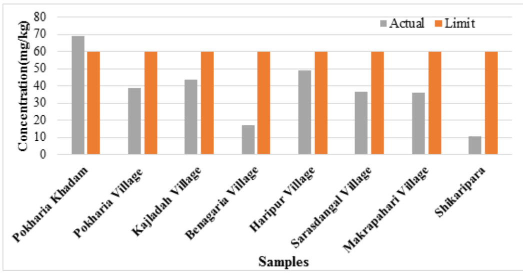
Concentration of Iron



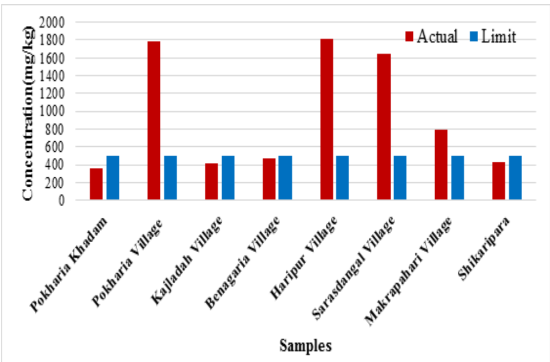
Concentration of cadmium



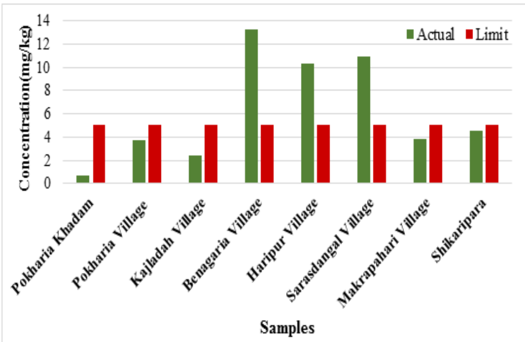
Concentration of copper



Concentration of Zinc



Concentration of Manganese



Concentration of Lead

Figure 6: Concentration of metals over different region near shikaripara

4. Conclusion

Shikaripara, being a smaller town within Dumka district, is not typically associated with large-scale mining activities. Instead, it is more known for its rural and agricultural landscape.Since mining is taken in large quantities the soil in that particular area is polluted with heavy metals and effecting the agriculture and human slightly. This is tested with ICP-MS equipment to know the particles of heavy metal present in the soil with their values. The comparative values with near regions of Dumka are also presented to see the variations in the soil particles. Precautions should be taken by the government to avoid these drawbacks and implement new activities to improve the soil quality.

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Conflict of interest:

The authors declare no conflict of interest.

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