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Impact of Bauxite Mining on Soil: A Case Study of Bauxite Mines at Udgiri, Dist-Kolhapur, Maharashtra State, India

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Abstract

Bauxite mining being an impermanent activity, at most times, leaves long term negative impact on the environment. The study area i.e. two bauxite mines at village Udgiri, Dist-Kolhapur, forms a part of globally acknowledged biodiversity rich Western Ghats which are now under tremendous pressure. The present study is an attempt to trace out the impacts of bauxite mining on soil. Soil analysis result revealed that soils at two mine sites at Udgiri were deficient in nutrients such as Organic Carbon, Nitrogen, Phosphorus, Potassium, Calcium and Magnesium, with deteriorated physical soil parameters namely field capacity and water holding capacity, as compared to the soils from the adjoining forest, agriculture and plateau grassland sites. Thus the bauxite mining activity is responsible for alteration in the basic physico-chemical properties and composition of the local micro and macro ecosystems, which is bound to have adverse environmental impact on biodiversity, soils and hydrology in the catchment of dams and adjoining areas as result of changed landuse.

Keywords: Bauxite mining, soil, nutrient loss, erosion.

Introduction

Soil is a dynamic, natural body that occurs on the earth's surface which supports the growth of plants. Soils are formed by the decomposition of rock and organic matter over many years[1]. Mining causes negative environmental effects such as degradation of water quality, loss of forest and wildlife, landscape deterioration, spreading of spoils creating wasteland, noise pollution, degradation of agricultural lands etc.[2]. Mining of minerals is very location specific and often a onetime exploitative activity which adversely affects the environment. Mining industry affects the agricultural land area and induces human settlement pattern thereby causing disruption of social relations[3]. Open cast quarrying is responsible for several negative environmental and socio-economic impacts, particularly when the quarrying is carried out haphazardly and not as per prescribed norms and regulations[4]. Mining and metallurgical activities cause greater perturbation and devastation of both terrestrial and aquatic environments which has large scale ramifications[5]. Rapid degradation of disturbed soil with substantial macronutrient losses were recorded from karst bauxite mine in Jamaica[6]. Mining activities in the Western Ghats of Maharashtra has disturbed the habitat of various species which is affecting the diversity of Pteridophytic species in the area[7]. Bauxite mining activity, legal and illegal, in the Western Ghats of south Maharashtra has caused environmental degradation due to various factors such as dust pollution, noise pollution, loss of biodiversity, vegetation loss and pressure on local resources[8].

Top soil management plays an important role reclamation plan to prevent nutrient losses[9]. Mining can become more environmental friendly and sustainable by adopting and integrating social, environmental and economic developments that will minimize the environmental impact of mining operations[10].

Material and Methods

The study area comprised of two bauxite mines (M/S Swati Minerals-Mine area 776.78 Ha. and M/S Prakash Anadrao Gaikwad-Mine area-254.51 Ha.) adjoining village Udgiri, Taluka-Shahuwadi, District-Kolhapur of State of Maharashtra. This area is a part of Western Ghats which are one of the 25 hotspots of global biodiversity.

The physico-chemical characteristic of soil was carried out to assess the effect of bauxite mining on soil properties in the neighbouring region. The investigation included analysis of soils collected from identified sites near the bauxite mine at Udgiri. Soil samples at 10-20cm depth from the ground surface were collected at six selected sites near bauxite mines. These samples were composites of 5-6 sub samples as recommended by Maiti[11]. Twelve physico-chemical parameters in surface soil were studied at the six selected sites around the bauxite mines at Udgiri to assess the possible environmental effect of bauxite mining on the soil properties. Seasonal sampling for post monsoon and pre monsoon period from October 2009 to May 2011 was carried out.

The soil samples were collected from Forest soil (FS), Plateau soil (PS), Agriculture soil (AS 1 and AS 2) from Guravwadi and

Udgiri villages respectively and Mine soil (MS1 and MS2) from Mine 1 and 2 respectively. The location of these six sampling sites is given in figure-1.

Results and Discussion

Typical bauxite ore is covered by thick lateritic layer which acts as a recharge zone for groundwater and are also the origin of streams and rivers. In the study area this lateritic zone, also called as overburden, is being continuously removed with the progress of mining activity to access the bauxite ore below this lateritic zone. Bauxite mining associated activities like blasting, removal of ore; movement of heavy vehicles, is affecting the physical landscape characteristics and ecology.

It was studied from the topsheets and Google Earth satellite imageries that due to high elevation of the Udgiri mining sites at about 926 to 1026 m above Mean Sea Level (MSL) in the hilly Western Ghats, a number of first order streams originate on or near the mines of which 12 have been completely disrupted due to mining activity (figure-2). Dams namely Warna, Kansa and Kandvan lie in the 10 km radius area from these mine sites at Udgiri.

Overburden dumps of height in the range of 5m to 6m were observed at both the mines near village Udgiri. Most overburden dumps were found to be without any retaining walls (figure-3) and at some places where the walls constructed were insufficient of merely 0.4 to 0.6m in height at mine sites. As the area receives high rainfall in the range of 1620 to 3450 mm per year it suffers from large amount of soil erosion which ultimately is affecting the soil properties as well as water resources in the study area.

Soil is a major basic factor in any terrestrial habitat landuse. In general the recorded parameter values revealed a clear pattern while compared within the four categories of soils collected from namely forest, plateau, agriculture and bauxite mines. The results of the study are given in table-1.

Field capacity (FC) percentage of a soil is defined as the amount of water held in soil after the excess of gravitational water has drained away under free drainage and minimum evaporation. The forest soil had the highest (62.50%) field capacity followed by the agriculture soils (above 42.00%) from Udgiri and Guravwadi, while the two mine soils recorded much lower percentage of field capacity (between 16.00 to 19.00 %). The plateau soil as usual had relatively lower field capacity (28.20 %).

Water holding capacity (WHC) of soil usually refers to amount of maximum water which can be held by the saturated soil. Both, the forest soil (51.70%) and the agriculture soil (40.40 %) respectively from Udgiri showed higher WHC. The two mine soils recorded lower WHC between 12 to 14 %. The plateau soil (20.90%) had better WHC then the mine soils, despite being a thin soil profile on the stony outcrops. Apparently lack of macro and micro nutrients, and humus are the major reasons for lower values of field capacity (FC) and water holding capacity (WHC) of mine soils.

pH which determines the basic and acidic properties of soil, plays a significant role as nutrients namely Nitrogen (N), Potassium (K) and Phosphorus (P) are carried by soil which are needed by plants in varying amounts for their growth[12]. The pH values of the sites varied from 7.20 to 8.10 with forest soils being the lowest and mine sites with highest pH value 8.10. Presence of clay and lack of organic material may be the major reason for the alkaline nature of these soils.

Table-1
Average values of twelve soil parameters at six sites near Udgiri mining sites

Sr. No.	Soil Parameters	Name of the site					
		Forest soil	Plateau soil	Udgiri (agri)	Guravwadi (agri)	Mine soil 1	Mine soil 2
1.	Field capacity %	62.50	28.20	42.00	42.00	18.60	16.60
2.	Water holding capacity %	51.70	20.90	40.40	29.20	14.00	12.33
3.	pH	7.20	7.80	7.60	7.80	8.10	8.10
4.	Organic carbon %	2.50	2.50	3.20	4.50	0.75	0.45
5.	Nitrogen Kg/ha	3.00	3.72	17.20	7.00	00	00
6.	Phophorus Kg/Ha	0.04	0.02	0.03	0.02	0.02	0.03
7.	Potassium Kg/Ha	208.30	70.10	127.15	135.38	9.50	9.25
8.	Ca mg/lit	119.80	63.70	95.80	92.10	34.29	16.38
9.	Mg mg/lit	20.50	4.70	27.30	34.40	4.00	1.69
10.	Si g/ Kg	0.52	0.61	0.53	0.60	0.81	1.29
11.	Fe g/Kg	140.00	78.00	365.00	179.90	551.00	469.00
12.	Al g/Kg	52.40	44.00	37.50	38.70	361.00	342.50

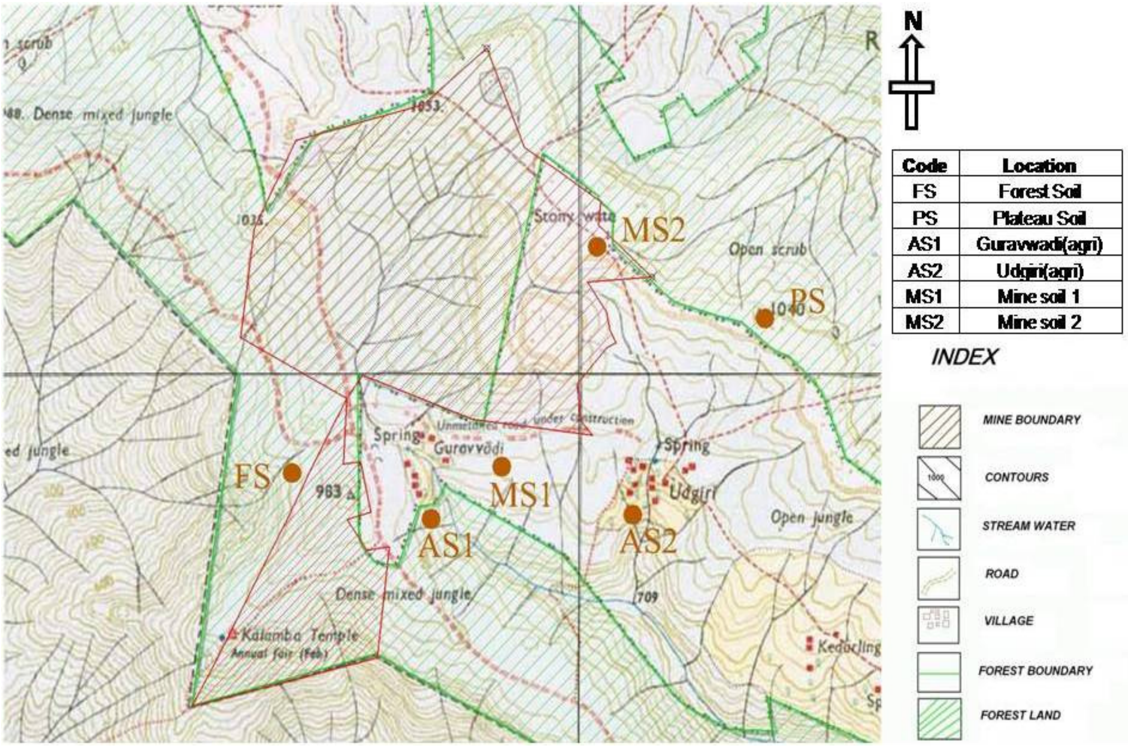

Figure-1
Location map of six soil sampling sites near the bauxite mines at Udgiri

Figure-2
Diversion of natural stream at bauxite mine M/S Prakash AnadraoGaikwad

Figure-3
Overburden dump without retaining walls M/S Swati Minerals, Udgiri

Organic carbon is an important parameter of any soil, which improves both the physical and chemical properties of soil and has several favourable effects on soil quality. The quality of soil improves if the organic carbon in the soil is greater than 0.8%[13]. The organic carbon values varied from 0.45 to almost 4.5 %. The organic carbon content of both the mine sites was found to be very low i.e. MS1 (0.75%) and MS2 (0.45%) respectively. As expected there was higher and almost equal organic carbon content in forest soil and plateau soil (2.50%). On the other hand, the agriculture soils at Udgiri and Guravwadi had (3.20%) and (4.50%) organic carbon respectively. This was due to higher amount of organic substances, as a result of ongoing agriculture practice using organic manure, in these soil samples.

Nitrogen is the chief growth promoting nutrient element which influences soil productivity and is an important element for plant development. In the present study the available nitrogen content in the soil ranged from 3.00 to 17.20 Kg/ha. Available nitrogen content was found to be highest at Udgiri agriculture soil (17.20 Kg/ha). While at the two mine sites the available nitrogen recorded was zero. Forest and plateau soils had reasonable nitrogen content (figure-4).

Phosphorus is an essential element classified as macronutrient since it is required in relatively large amounts by the plants. In the present investigation the available phosphorus values ranged from 0.02 to 0.04 Kg/Ha. Plateau soil, Guravwadi agriculture soil and mine soil1 recorded uniformly lower Phosphorus values (0.02Kg/Ha). While interestingly the forest soil showed highest Phosphorus content with value of 0.04 Kg/Ha.

Potassium is a key nutrient and plays a vital role in the building of protein and reduction of diseases in plants. Forest soil and both the agricultural soils at Guravwadi and Udgiri showed high potassium level above 125.00 kg/Ha. High potassium content in forest soil (208.30 Kg/Ha) is due to its undisturbed nature and presence of considerable amount of organic matter in the soil. Also in case of agricultural soils, to increase the fertility of soil, potassium is added to the soil and hence occurs in higher proportion. Plateau soil showed optimum level of potassium of 70.10 Kg/Ha while both mine soils lacked heavily in potassium content due to the degraded and disturbed nature of the soil.

Calcium is considered to be a secondary plant nutrient and maintains chemical balance of soil. It was found that the soil nutrient values were highest in forest soil (119.80 mg/lit), followed by Udgiri agriculture (95.80 mg/lit) and Guravwadi agriculture soil (92.10 mg/lit). Conversely mine site 1 and mine site 2 showed low calcium content with values of 34.29 mg/lit and 16.38 mg/lit respectively (figure-5). The values of the nutrient were intermediate (63.70 mg/lit) in plateau soil.

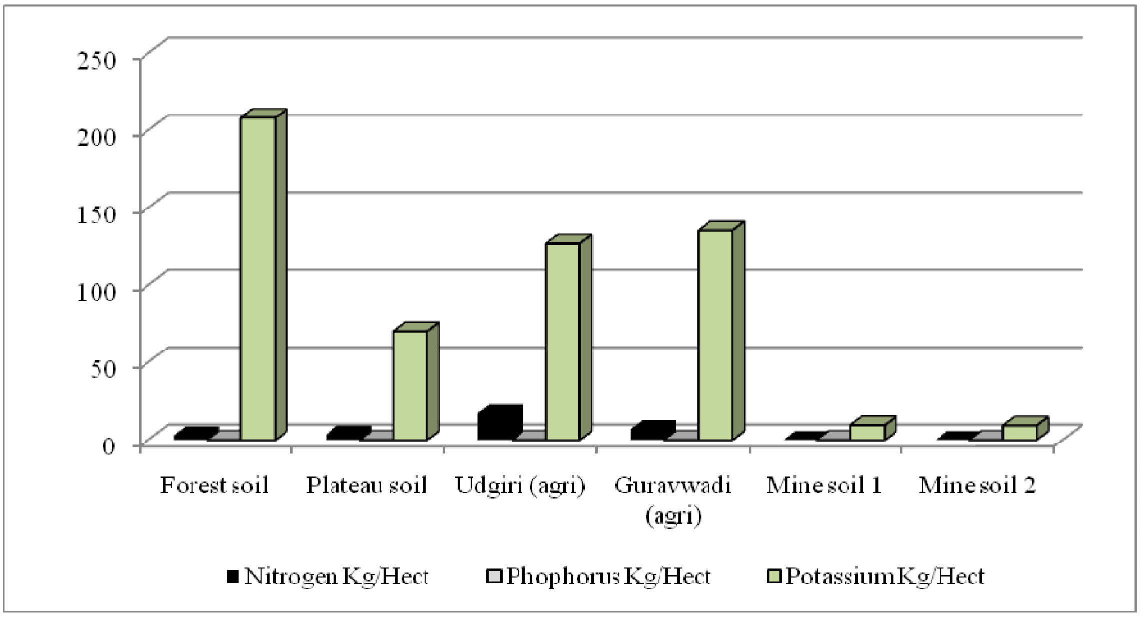

Figure-4
Nitrogen, Phophorus and Potassium content in soil at six study sites

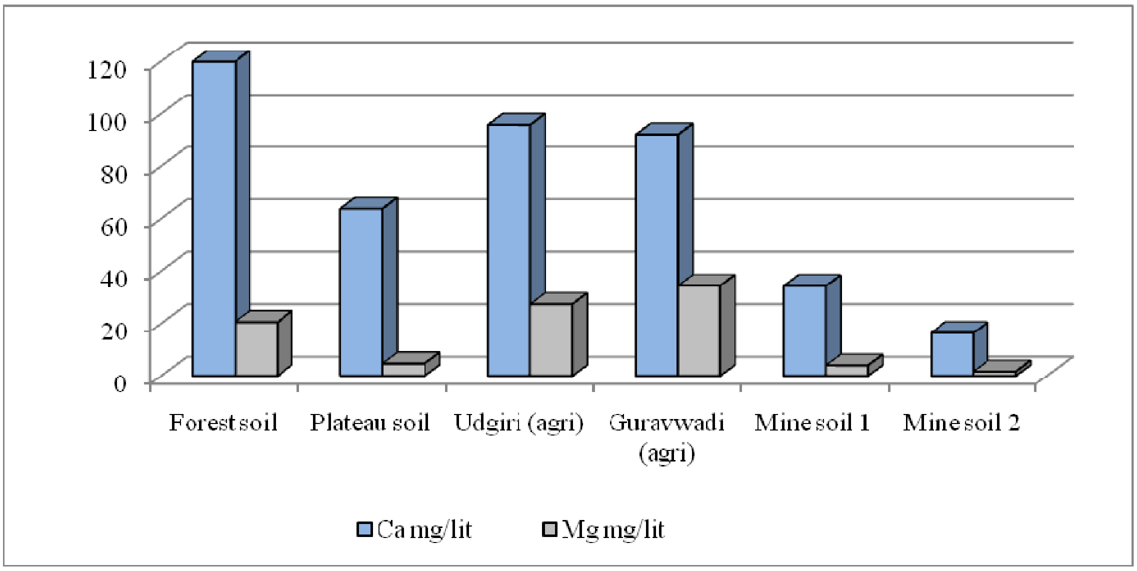

Figure-5
Calcium and Magnesium content of soil at six study sites

Magnesium forms an important part of chlorophyll, a plant pigment critical in photosynthesis. Sites namely forest soil (20.50 mg/lit), Udgiri agriculture soil (27.30 mg/lit) and Guravwadi agriculture soil (34.40 mg/lit) were found to be rich in magnesium content. On the other hand plateau soil (4.70 mg/lit), mine soil 1(4.00 mg/lit) and mine soil 2(1.69 mg/lit) showed low magnesium content.

Occurrence of higher amount of primary macronutrients such as nitrogen, phosphorus and potassium (NPK) and secondary macronutrients (calcium and magnesium) in agricultural soils were evident as these nutrients are annually added to the soils in the form of fertilizers and manure to increase crop productivity. Also reasonably higher level of these nutrients observed in case of forest and plateau soils are due to the fact that the natural biogeochemical cycles are undisturbed in both habitats. While, mine surface soils being disturbed due to the opencast mining excavation activities in reality are only the subsurface soil lack in the nutrients.

Silica is a common constituent in soils. Silica content in study sites marginally varied from 0.52 g/Kg to 1.29 g/Kg.

Agricultural soil, plateau soil and both agriculture soil at Udgiri and Guravwadi showed silica content above 0.50g/Kg. While the two mine soil sites recorded relatively higher silica content with values of 0.81 g/Kg and 1.29 g/Kg in mines MS1 and MS2 respectively. Higher values of silica in mine soils are due to fact that the low grade ore is rich in silica content.

The iron content in the soils in the Western Ghats region of Kolhapur is relatively high and it gives the characteristic red colour to the soil. The exposed Mines soil 1 (551.00 g/Kg) and mine soil 2(469.00 g/Kg) showed higher Iron (Fe) levels in soil in the study area. On the other hand plateau soil (78.00g/Kg) recorded lowest Fe content (figure-6). The agriculture soils at both the sites and forest site soils showed intermediate but lower values in decreasing order. There was little erratic pattern of Fe values in the soils in the study area.

Aluminium content was found to be very low in the forest soil (52.40 g/Kg), Plateau soil (44.00g/Kg), and both agriculture sites i.e. Udgiri agriculture soil (37.50 g/Kg) and Guravwadi (38.70 g/Kg). However, at the mine sites, mine soil 1(361.00 g/Kg) and mines oil 2 (342.50 g/Kg) recorded very high levels of aluminium content. It is important to note that the higher values of silica, iron and aluminium in the soils at both the mine sites are due to the fact that the bauxite ore is composed of Al_2O_3, Fe_2O_3 and SiO_2.

Conclusion

The present study revealed that bauxite mining activity is responsible for alteration in the basic physico-chemical properties of the local soils and this is causing a major adverse environmental impact as the result of changed land use on the soils in the study area. These mining operations being open cast and in the ecosensitive corridor region of the Western Ghats, are resulting in biodiversity loss, loss of nutrients and microbial properties of the natural fragile soil ecosystems.

The soils in the mining areas are affected by most of the mining activities such as blasting, drilling, removal of natural and stabilized vegetation and excavation of shallow top soil, storage of low grade ore and dumping of overburden on natural vegetation, clearing of land for construction of ancillary facilities and movement of heavy machinery, dumpers and trucks etc. In all mine soils studied the concentrations of organic carbon, available nitrogen, phosphorus, calcium and magnesium have been found to be poor, as being lost due to mining activity, as compared to their values in the neighbouring control sites in forest and plateau soils.

Aluminium toxicity is found to be a main factor which limits plant growth in strong acid soil. Toxic effects on plant growth have been found to be dependent on several physiological and biochemical pathways[14]. In present study though the mine soils were not acidic they contained very high aluminium levels which can have a negative effect on the growth of plants. Earlier studies have shown that the microbial biomass decreased with increasing aluminium independent of the pH[15].

Not only plants are damaged by high concentration of available Al but free living micro-organisms are inhibited too. This in turn affects the biogeochemical cycles in the soil ecosystem which ultimately affects the overall soil productivity. The nutrients released due to microbiological activity are constantly lost if the biological reclamation is not done within shelf life of soil[16].

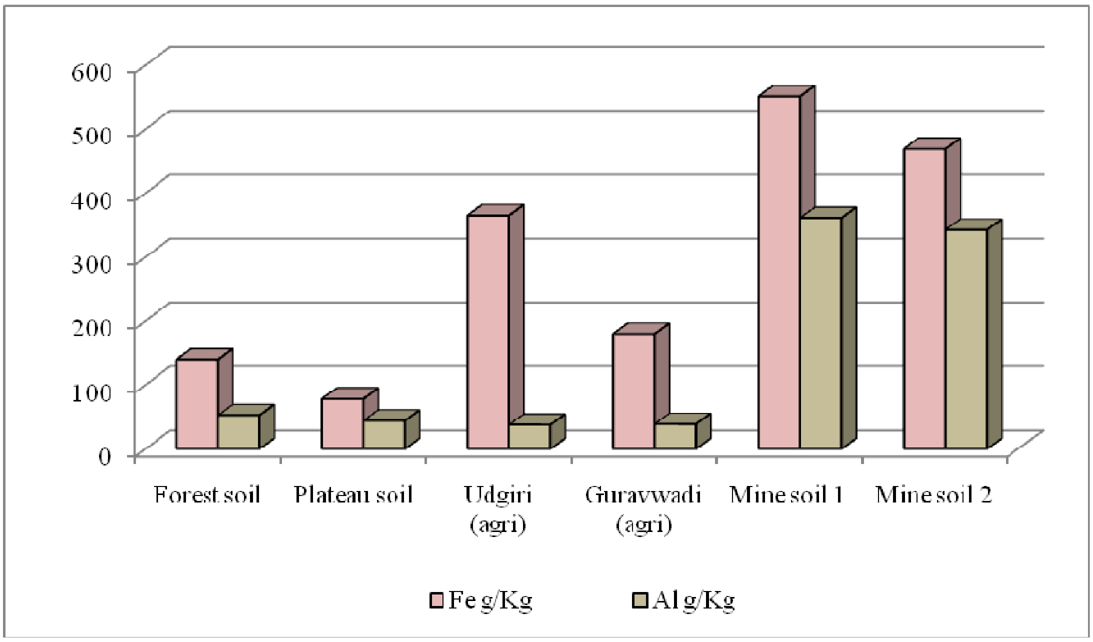

Figure -6
Al and Fe content of soil at six study sites

In the bauxite mines at Udgiri, the top soil is not handled properly, as it is not dumped appropriately for restoration use after mining activity is terminated.

This result into mixing of topsoil with the deep soil overburden and rocks and thus the soil fertility, which is an important resource for mine restoration and land management, is gradually but permanently lost. Ignorance, apathy and lack of will for proper implementation of the existing mining regulations have led to serious environmental degradation and ecological damage to the soil in the mining areas.

To undertake the appropriate, mandatory eco-friendly mining and reclamation methods, the bauxite mining operations and Environmental Management Plan (EMP) need to be carefully and scientifically planned and implemented through appropriate sustainable manner to have minimum environmental damage. Unfortunately the existing mining practices are far below the expected standards with total disregard to the mandatory systematic restoration of the mined area. This becomes more crucial when the study area in Kolhapur district falls in the part of the Western Ghats which is designated as one of the 'World Biodiversity Hotspot'[17], as Natural Heritage site of International Importance by the UNESCO[18] and as an Ecosensitive Area (ESA) by the Ministry of Environment and Forest (MoEF), Government of India[19].

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References

1. Zaware S.G., Environmental Impact Assessment on Soil Pollution Issue about Human Health, *International Research Journal of Environment Sciences,* **3(11)**, **(2014)**

2. Lamare R. And Singh O.P., Degradation in water quality due to limestone mining in east Jaintia Hills, Meghalaya, India, *International Research Journal of Environment Sciences,* **3(5)**, 13-20, **(2014)**

3. Debasis G., A case study on the effects of coal mining in the environment particularly in relation to Soil, Water and Air causing a Socio-economic Hazard in Asansol-Raniganj Area, India, *International Research Journal of Social Sciences*, **3(8)**, 39-42 **(2014)**

4. Lad R.J. and Samant J.S., Environmental and Social Impacts of Stone Quarrying- A Case Study of Kolhapur District, *International Journal of Current Research*, **3(8)**, 39-42, **(2014)**

5. Ahanger F.A., Sharma H.K., Rather M.A. and Rao R.J., Impact of Mining Activities on Various Environmental Attributes with Special Reference to Health Impacts in Shatabdipuram, Gwalior, India, *International Research Journal of Environment Sciences,* **3(6)**, 81–87 **(2014)**

6. Harris A.M. and Samson O.N., Post-mining deterioration of bauxite overburdens in Jamaica: storage methods or subsoil dilution?, *Environ Geol,* **54**, 111–115 **(2008)**

7. Shaikh S.D. and Dongare M., Effects of Mining on the Diversity of the Pteridophytes from the Western Ghats of Maharashtra (India), *World Applied Sciences Journal*, **11(12),** 1547-1551 **(2010)**

8. Lad R.J. and Samant J.S., Environmental impact of bauxite mining in the Western Ghats in south Maharashtra, India, *International Journal of Recent Scientific Research*, **4(8),** 1275-1281, **(2013)**

9. Sheoran V., Sheoran A.S. and Poonia P., Soil Reclamation of Abandoned Mine Land by Revegetation : A Review, *International Journal of Soil, Sediment and Water*, **3(2), (2010)**

10. Kumar P.N., Review of Sustainable Mining Practices, *International Research Journal of Earth Sciences*, **2(10)**, 26-29, **(2014)**

11. Maiti S.K., Handbook of Methods in Environmental Studies : Air, Noise and Overburden Analysis, (Volume 2, ABD Publishers, Jaipur), 20-60 **(2003)**

12. Biswas T.D. and Mukherjee S.K., Textbook of Soil Science, (2nd Edition, Tata McGraw- Hill Publishing Company Limited, New Delhi), 8-12 **(1994)**

13. Ghosh A.B., Bajaj J.C., Hassan R. and Singh D., Laboratory Manual for Soil and Water Testing, (Division of Soil Science and Agricultural Chemistry, IARI, New Delhi, India), 1122, **(1983)**

14. Roy A.K., Sharma A. and Talukder G., Some Aspects of Aluminium Toxicity, *The Botanical Rev.*, **54**, 145-178 **(1988)**

15. Illmer P., Marschall K. and Schinner F., Influence of Available Aluminium on Soil Micro-Organisms, *Lett. Appl. Microbiol*, **21**, 393–397 **(1995)**

16. Ghose M.K., Effect of Opencast Mining on Soil Fertility, *Journal of Scientific and Industrial Research*, **63**, 1006-1009 **(2004)**

17. Myers Norman, Mittermeier Russel A., Mittermeier Cristina G., Fonseca Gustavo A.B. da and Kent Jennifer, Biodiversity Hotspots for Conservation Priorities, *Nature*, **403**, 1-8 **(2000)**

18. UNESCO, Decision Adopted by the World Heritage Committee at its 35th Session, UNESCO, 1-283, **(2012)**

19. Ministry of Environment and Forest (MoEF) Order, Directions under Section5 of the Environment (Protection) Act, 1986, F. No. 1-4/2012-RE(Pt), MoEF, Government of India (GOI), dated 13-11-2013, **(2013)**