Jr. of Industrial Pollution Control 33(2)(2017) pp 1647-1654
www.icontrolpollution.com
Research Article

HEAVY METAL ACCUMULATION PATTERN IN SOIL AND SEEDLINGS AND IN LEAVES OF MATURE TREE SPECIES AT GEVRA COAL MINE AREA IN CHHATTISGARH, INDIA

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(Received 29 November, 2017; accepted 22 December, 2017)

Key words: Heavy metal, Coal mines site, Seedling, Soil, Mature tree

ABSTRACT

It becomes now significant to determine impact of coal mine activity by assessing heavy metal distribution between soil and its accumulation in forest trees at contaminated site and their peripheries. Due to heavy metal contamination in soil it enters into the plants then move to food chain. In present study the heavy metal such as Lead (Pb), Zinc (Zn), Cu (Copper) and Cadmium (Cd) concentrations in soil and plants (seedling and mature tree leaves) have been analysed to see the effect of Gevra coal mine, Korba district, Chhattisgarh. It has been found that the high concentration of these metals in the soil at mine site is higher than comparison to control site. The accumulation pattern shows that zinc has higher accumulation (0.998) mg/l followed by copper (0.45) mg/l and lead (0.236) mg/l at contaminated site than control site zinc (0.194, copper 0.08 and lead 0.099) mg/l respectively. Cadmium was recorded below detectable range in all soil samples. In present study three tree species Shorea robusta, Diosyprous melanoxylon and Cassia siamea were taken for analysing these metal accumulation in its seedling and leaves of mature tree. It has been observed that the concentration of heavy metal is higher in seedlings than in mature tree leaves in Shorea robustaand Cassia siamea. This study provides a comprehensive assessment of soil heavy metal pollution produced from coal mines and coal fired thermal power plants and provides supportive information in pollution control and environmental management.

INTRODUCTION

Minerals are essential raw materials in industrialization and economic development. Coal, being a primary source of energy plays a vital role in India due to huge availability of coal. India ranks fourth in coal reserve after USA, Russia and China. It has been established by the exploration carried out by GSI, CMPDI and other agencies that 298.91 billion tonnes of coal reserves up to 1,200 m depth is available in the country. The state of Chhattisgarh alone is having 16% of coal reserves and ranks second in the coal production by contributing 18% of total national production (Mineral resources department, C.G. 2017). The challenge of increasing the coal production to meet the ever-growing needs of the country has been met by the phenomenal increase in coal production from opencast mines. India is the third largest producer of coal from open cast mines (Chaulya, 2003).

Removal of fertile top soil layer and vegetation cover during mining activities has environmental consequences. Soil pollution by heavy metals is a significant environmental problem worldwide (Alloway, 1995). Coal burning produces millions of tons of solid waste products annually, including fly ash, bottom ash, and flue-gas desulfurization sludge that contain mercury, uranium, thorium, arsenic, and other heavy metals. Heavy metals like zinc (Zn) and copper (Cu), are elements essential for the normal growth of plants and living organisms. However, high concentrations of these metals become toxic. Heavy metals like lead (Pb) and cadmium (Cd), may

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be tolerated by the ecosystem in low concentrations, but it become harmful at greater concentrations (Alloway and Ayres, 1997). Elevated concentrations of both essential and non-essential heavy metals in the soil can lead to toxicity symptoms and growth inhibition in most plants (Hall, 2002). The concentration of naturally occurring metals in soil is generally very low and tends to remain in very low concentration. Human activities, which involve large quantities of metal being emitted into the environment, have dramatically increased its concentrations (Gowd, *et al.*, 2010). The content of heavy metals (HM) for different solid fuels varies from 0.5 ppm (for Cd, Hg) up to several thousands ppm (for Ba, Zn) (Tillman, 1994). Every million tonne of coal extracted by surface mining methods damages surface soil area of about 4 ha in India (Ghose, 2004). The highest source of heavy metal contaminating soil annually in worldwide is coal ash (Nriagu and Pacyna, 1988). Alone from coal ash the arsenic, (1.5-13) cadmium, (149-446) chromium, (93-335) copper, (0.37-4.8) mercury, (56-279) nickel, (45-242) lead and (112-484) zinc (1000 tonnes per annum) is produced. Soil heavy metal and risk assessment were analysed by (Fan-xin, *et al.*, 2016) in Xingren coal mine, China. They recorded that the aesenic had highest contamination level followed by mercury and lead in soil.

Plants contribute to the circulation of heavy metals in the food chain through their active and passive absorption. These metals accumulate in tissues of plants and subsequently by animals and humans. High levels of heavy metals concentration initiate a wide range of physiological and metabolic alterations in plants (Dubey, 2011; Villiers, *et al.*, 2011). Chlorophyll synthesis process is interfere by heavy metal through direct inhibition of an enzymatic step or by inducing deficiency of an essential nutrient (Van and Clíjsters, 1990). The most widespread visual evidence of heavy metal toxicity is a reduction in plant growth (Sharma and Dubey, 2007) including decrease in the rate of seed germination (Khan, 2013), reduction in the chlorophyll content (Pant, *et al.*, 2011). Leaf chlorosis, necrosis, turgor loss, crippled photosynthetic apparatus, often correlated with progressing senescence processes or with plant death (Dalcarso, *et al.*, 2010; Carrier, *et al.*, 2003). (Ćujić, *et al.*, 2016) evaluated heavy metal pollution in soil due to coal fired thermal power plants surrounding the largest thermal power plant in Serbia. They observed that peripheries of thermal power plant are contaminated by heavy metal and maximum contamination factor was determined for nickel followed by zinc and cadmium. This study shows that not only coal mining but coal fired thermal power plant also contributed heavy metal contamination in surrounding area.

Studies on soil and forest tree species of metal-contaminated sites and their peripheries are essential for an accurate assessment of metal toxicity of soils and aerial plant parts in relation to the possible toxic impacts. Hence this study of effect of soil and vegetation contamination by heavy metals in coal mine site and their peripheries has been taken because it is important to asses toxic accumulation pattern on tree seedling and mature trees.

STUDY AREA

The study area selected for the present study fall in the vicinity of open cast coal mines (Gevra) and coal based thermal power plants in Korba district, Chhattisgarh. State have 16% of coal deposits in India. The 44483 million tonnes coal have been estimated in 12 coalfields of the state located in Raigarh, Surguja, Koriya and Korba districts in this state. Korba coalfield is located in the north eastern part of the Chhattisgarh and has maximum coalflieds. Presently there are eight underground mines and five opencast mines. Korba Coal Field is extended from 22°15' and 22°30' North latitudes to 82°15' and 82°55' east longitudes over an area of 520 Sq.km. Gevra Opencast Block is located in the south-central part of Korba. It is biggest open cast coal mine in India. In the vicinity of Gevra mines area there exist forest dominated by Sal forest.

MATERIALS AND METHODS

Sample collection

For the analysis of the heavy metal concentration in the area nearby open cast coal mines soil, plants and seedling have been collected from nearby the mine area and from different transect distance from it. Soil sample have been collected from eight different sites in three replicates. Soil sample were collected from 0 cm to 20 cm depth, the sample were kept in sterilized bag and brought to the laboratory. The samples were air dried and sieved through 2 mm sieve and stored for analysis in separate sterilised polybags.

Three tree species were selected which are naturally growing nearby the study area. These are *Shorea robusta*, *Diosyprous melanoxylon* and *Cassia siamea*. All the three species seedling and mature tree leaf sample were collected for the analysis of the heavy metal accumulation. 5 to 10 seedlings of each species were uprooted and 10 to 15 leaves of each mature tree species were collected randomly and kept in the sterilized polybag. During sample collection, it was ensured that different plant samples of each species had same physiological age and appearance.

To study effect of heavy metal concentration in soil eight sites were selected. These sites are broadly categorized according to its functionality. Category 1 site is the site where mining is taking place and leading to direct soil pollution by erosion and dumping of heavy metals which can not be utilized further. Category 2 site is situated near coal thermal power stations which are emitting heavy metal from air plumes and have water discharge area and dumping site via solid wastes. Of the eight sites, two are in Gevra coal mine area (site-1 and 2) where mining is very active currently. These two has been chosen at central as well as 100 m away from main Gevra coal mine site. Three sites are near Kobra thermal power station where active power generation activities are pursued throughout the day and night. The sites are chosen away from 100 m and 1000 m from central site (site- 3, 4 and 5) respectively. Two sites (site-7 and 8) are choosen in Pali (38 km from source) and Mugadeeh (40 km from source) as they are far away from main thermal power sites. Site-6, Lakhanpur (10 km from source) has been chosen where very active coal loaded vehicles are actively passing through. For heavy metal analysis in seedling and tree leaves three sites have been selected these sites are site-1, site-7 and site-8. All distance to sites were measured in the ariel distance.

Digestion of the soil sample

About 5g of the homogenized sample was taken and made it to fine powder and further dried in hot air oven at 70°C for 72 hrs. The 0.1 g each was taken for performed digestion added with 9 ml of concentrated HCl and 3 ml concentrated HNO_3 into the beaker covered with watch glasses on a hotplate for 3 hr at 110°C. The digests were cooled and 20 ml 20% HNO_3 was added. After cooling and filtering through Whatman no. 42 filter paper mixture was diluted to 100 ml with double distilled water (Chen and Ma, 2001; Hse, *et al*., 2002).

Digestion of Plant samples

The 0.5 mg of powdered plant samples were added with 5 ml of concentrated nitric acid. The samples were then heated for 60 min at 95°C, and allowed to cool. The 1-2 ml of 30% H_2O_2 was added with repeat heating of mixture and addition of H_2O_2. Until about 1 ml of acid remained again continued the heating and added concentrated HNO_3 in necessary volume until digestion became complete as was shown by a light colour, clear solution. After the digestion, the extract was cooled and filtered and made it up to 100 ml by adding doubled distilled water (APHA, 1998; Fakayode and Onianwa, 2002; Ho and Tai, 1988; Zarcinas, *et al*., 1987).

The metal content was measured for lead (Pb), cadmium (Cd), copper (Cu) and zinc (Zn) using Flame Atomic Absorption Spectrophotometer (Varian model AA-240).

RESULT AND DISCUSSION

Heavy metal accumulation in soil

The concentrations of heavy metals in soil samples is summarised in the (Fig. 1). At site-1 the highest average metal content found in the soil was of Zinc (0.998) and followed by copper (0.45) and Lead (0.236) mg/l, due to its close vicinity of open cast coal mines. Site-2 is also nearby coal mine area so that all the metal concentration also found high, as shown in (Fig. 1-3). The lowest concentrations of metals were found in the samples of site-7, site-8. The mean value for zinc, copper and lead are (0.194, 0.158), (0.08, 0.09) and (0.099, 0.085) mg/l respectively.

Lead was found maximum (0.236 mg/l) at site-1, which is very close to the coal mine area. The lead accumulates in the surface ground layer and its concentration is decreases with soil depth. At site-6, concentration of lead is also higher (0.166 mg/l)

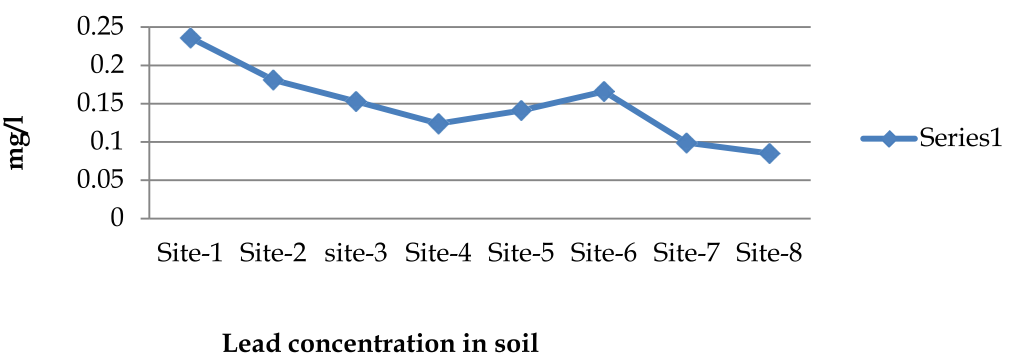


Fig. 1 Lead concentration in the soil sample at different transectional sites.

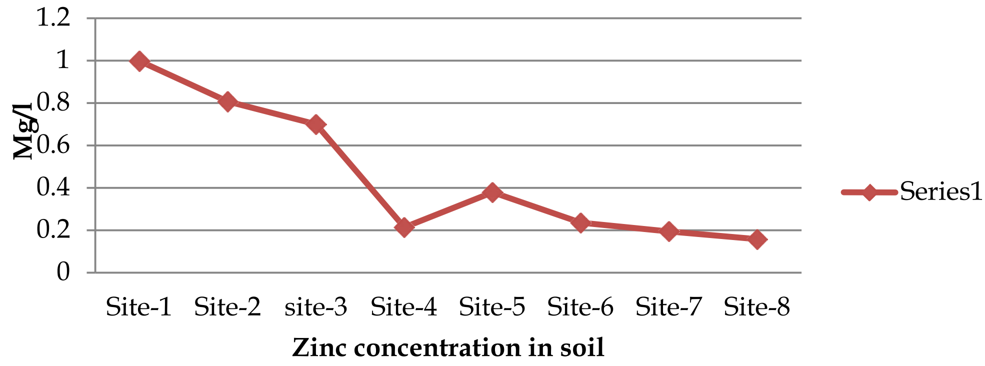


Fig. 2 Zinc concentration in the soil sample at different transectional sites.

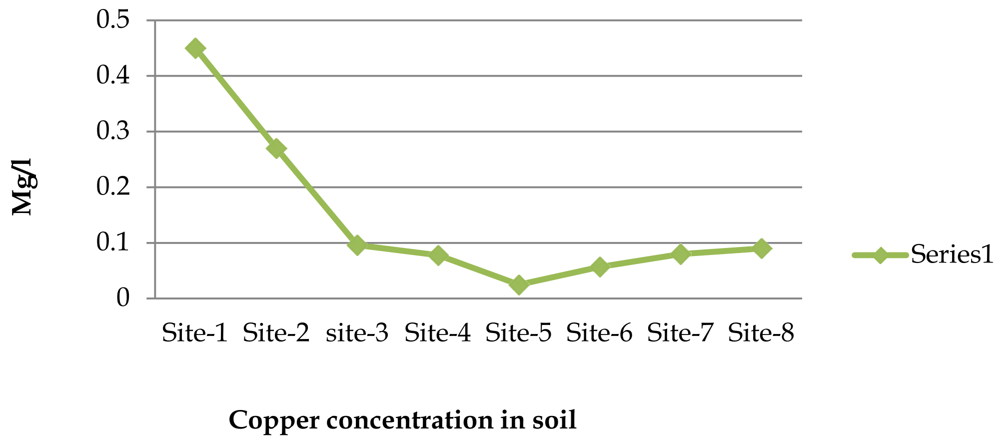


Fig. 3 Copper concentration in the soil sample at different transectional sites.

due to heavily polluted site by heavy vehicles which transport coal from mine area.

(Ogbonna, *et al*., 2012) reported the same trend while studying the heavy metal contamination at Onyeama coal mines site. They found that highest concentration of lead was within 1 m region of from the coal mines and the concentration was decreasing with distance. (Mattews, *et al*., 2012; Freitas, *et al*., 2004) also have found the lead contamination is higher in coal mines. It is reported that soil contaminated with lead cause decrease in the crop and tree productivity (Johnson and Eaton, 1980).

Zinc concentration in the study area was varies from 0.998 to 0.214 mg/l. High concentration of zinc was detected at the site-1 and 2 i.e., (0.998 and 0.807 mg/l) respectively. The source of the zinc can be related to presence of the coal mines and vehicular pollution. It was found that around thermal power plants (site-4) zinc concentration was minimum (0.214 mg/l).

(Rind, *et al*., 2013) conducted a study on Jamshoro thermal power plant and found that the zinc concentration were slightly high near thermal power plant. (Zhou, *et al*., 2007) reported the presence of high level of heavy metal concentration including zinc at mining area. Most of Zn is added in the soil during industrial activities, such as mining, coal, and waste combustion and steel processing. High level of Zn in soil inhibits plant metabolic functions which result in retarded growth and cause of senescence. Zinc toxicity in plants limit the growth of both root and shoot (Malik, *et al*., 2011).

Copper (Cu) is considered as a micronutrient for plants (Gang, *et al*., 2013) and plays important role in plant growth. In present study it has been found that the concentration of copper was in the range of 0.45 to 0.08 mg/l. The highest concentration of copper was found at Site-1 and 2 because of mining area. Mining activities generate a large amount of waste rocks and tailings, resulting in deposition of heavy metals at surface soil.

(Mattews, *et al*., 2012; Rind, *et al*., 2013) found that copper concentration were high in the mining area and near thermal power plant. Our results also show the similar trend of copper accumulation in soil. Excess of Cu in soil plays a cytotoxic role, induces stress and causes injury to plants. This leads to plant growth retardation and leaf chlorosis (Lewis, *et al.*, 2001).

Heavy metal accumulation in seedling and mature tree leaves

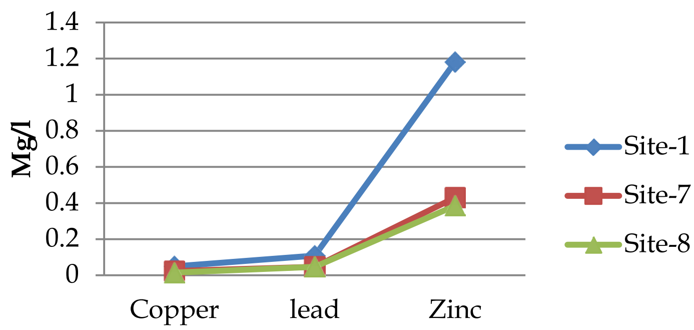
To study the accumulation and adsorption of heavy metal in plants, some of natural growing tree species have been selected for study which is growing in vicinity of coal mine area and also at control site. The concentration of heavy metals in leaves of mature tree and seedling of: *Shorea robusta* (Sal), *Diospyrous melanoxylon* (Tendu) *and Cassia siamea* (Cassia) were observed and are summarised in (Fig. 4 and 5).

It was observed that in seedling *Shorea robusta* all the tested heavy metals were detected except cadmium. The range of heavy metals accumulation was Zinc (0.1.182), Lead (0.109) and copper (0.05) mg/l varies at coal mine site (site-1). The lowest concentration for all three metals were detected at control site (site-8) as Zinc (0.385), Copper (0.015) and Lead (0.047) mg/l. There was significant difference recorded in the concentration of all three metals from site-1 to site- 8.

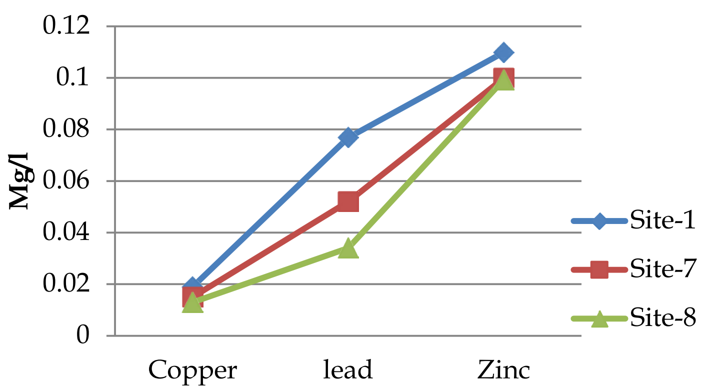
In mature *Shorea robusta* tree leaf accumulation of these metals were recorded. Lower than of its seedling (Fig. 4). This shows heavy metal accumulation is more in seedling stage of *Shorea robusta* than in mature tree. (Pant, *et al.*, 2011) have conducted experiment on *Shorea robusta* seedling by giving different dose of heavy metals and recorded the reduction in the total chlorophyll content and amino acid concentration. (Sengupta, *et al.*, 2011) also conducted study on *Mangifera indica* around coal fired thermal power plant and found that heavy metal concentration was high in the leaves of tree which were growing nearby the thermal power plant.

In *Cassia siamea* at the site of coal mine the concentration of heavy metals also varies as (Zinc (0.411) ≥ Lead (0.092) ≥ copper (0.084) mg/l) in seedling and in leaf of mature tree as (Zinc (0.372) ≥ Lead (0.075) ≥ copper (0.078) mg/l). At control site all the metals were present in the lower range than Site-1. The significant difference have been recorded between the metal concentrations from site-1 to site-8.

(Khan, 2013) conducted a study of effect of heavy metal on germination difference in *Cassia* species and found that *Cassia* species were sensitive to lead contamination and reported that the germination percentage decreased as lead concentration increased.



Heavy metal accumulation in Sal seedling



Heavy metal concentration in leaf of sal tree

Fig. 4 Heavy metal accumulation is Sal seedling and leaf of mature tree.

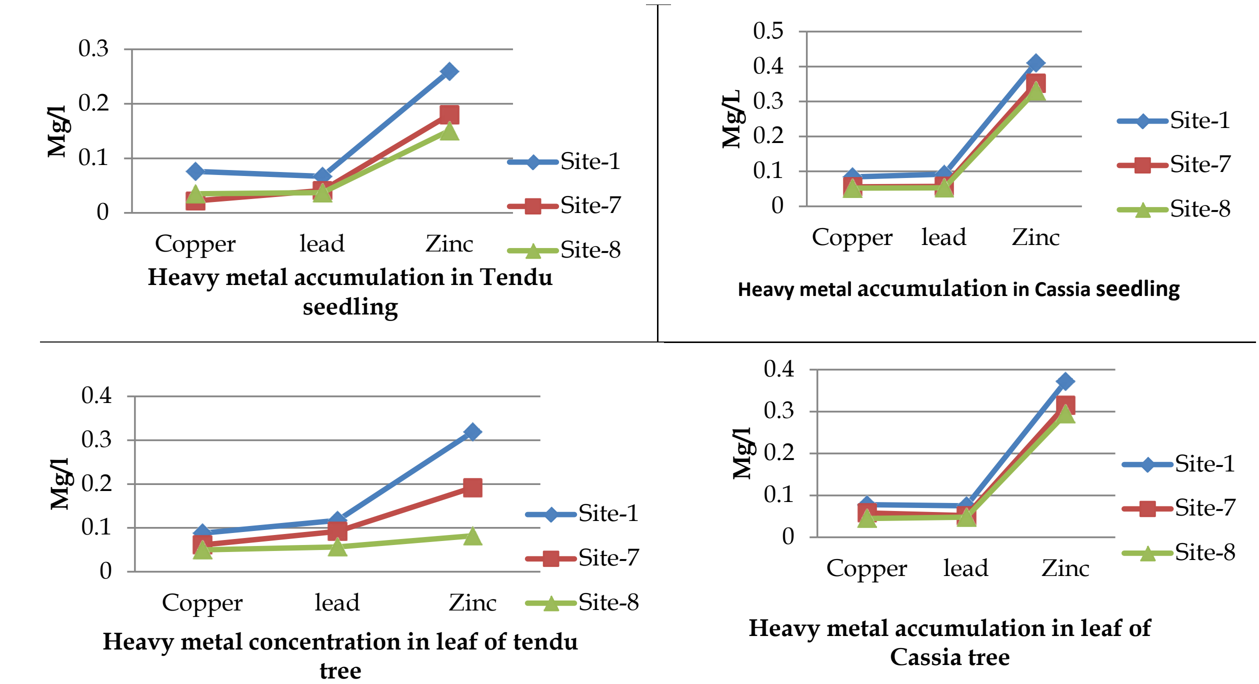


Fig. 5 Showing leaves metal accumulation pattern in seedlings and in leaves of mature tree of *Diospyrous melanoxylon* and *Cassia saeimia*.

(Patel, *et al*., 2015) analysed that tree growing nearby coal fired thermal power plant have high level of heavy metal accumulation in the leaves.

In *Diospyrous melanoxylon a* different trend has been observed, where more heavy metal accumulation was in the leaves of mature tree than seedling. In the seedling zinc, copper and lead accumulation was 0.26 mg/l, 0.076 mg/l and 0.067 mg/l respectively while in mature tree leaves it was 0.319 mg/l, 0.119 mg/l and 0.088 mg/l for zinc, copper and lead. This may be due to less accumulation capacity of this tree in early stage. (Doe, *et al*., 2011) studied on *Diospyrous melanoxylon* growing in coal mine spoils region and found presence of heavy metal in mature tree leaves.

CONCLUSION

Open cast coal mine activity effects the environment in various ways. Heavy metal contamination is one of the important aspects which influence the growth of seedling of forest tree species. Mining activities in the vicinity of the Dabaoshan Mine in China has been reported to have polluted 83 villages, 585 × 104 m^2 paddy fields and 21 × 104 m^2 ponds. (Jian-Min, *et al*., 2007). Tree species were contaminated with heavy metal and these metals reduced the germination percentage, chlorophyll content and influences of many physiological changes (Khan, 2013; Pant, *et al*., 2011). The *Shorea robusta* shows most accumulative nature for these metals. The soil constitutes an essential environmental, ecological and agricultural resource that needs to be protected from further degradation for healthy forest growth. In Korba district *Shorea robusta* is a dominating species and has very sensitive regeneration patter which got influenced and reduced by accumulation of heavy metals in forest soil due to open cast mining in Gevra. The *Diospyrous melanoxylon* is a hardy naturally growing forest tree species having physiologically strong rooting system with high level of water accumulation due to which heavy metal accumulation get diluted. *Cassia saeimia* is a introduced tree species in this area and has fast growth rate than *Shorea robusta* and *Diospyrous melanoxylon*.

ACKNOWLEDGEMENT

The author (S S Singh) is thankful to Ministry of Environment, Forest and Climate Change, New Delhi for sanctioning Major Research Project for this work.

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