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Effect of coal mining on soil composition

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Abstract- Various types of heavy metals are introduced into the soil by wastes produced as a result of opencast coal mining. Around the world, problems with metal toxicity and contamination are growing more prevalent. The plants only require a little amount of a few elements as nutrients, but if they are present in large quantities, they can be poisonous to the plants. In this investigation, soil samples were taken and tested for a number of common toxic heavy metals, including Cu, Cd, Cr, Fe, Hg, As, Pb, and Sn, from the coal overburden dump area and a nearby agriculture site, both located 5 kilometres apart. Through the use of Atomic Absorption Spectrophotometry, the soil's organic carbon content and cation exchange capability were also evaluated. This was used to report the amount of soil toxicity.

Key words: Heavy metals, Spectrophotometry, organic carbon, Coal mining activities

INTRODUCTION

Coal mining activities (coal extraction and solid waste disposal) impacts the physio-chemical properties of the soil. The mining activities majorly impact the soil porosity, penetration, microbial contents and make it prone to easier soil erosion.

Study related to soil erosion suggests that the cumulative effect on soil environment of coal area mainly includes soil erosion and soil pollution. Both of them degraded soil quality and reduced soil productivity. Mining subsidence together with declined regional underground water level and industrial construction of coal area changes the slope of ground surface, and then aggravates soil erosion.[1] Due to the long time dumping of coal gangue, hazardous substances are leached into the soil and result in soil pollution. The enrichment factor of heavy metal in the soil around the gangue is proportional to the history of coal mining. Compared to other heavy metal elements, Cu, Pb, Ni, Zn and Sn have stronger transfer abilities.[2] Contamination of the soil with these heavy metals may pose risks and hazards to humans and the ecosystem through: direct ingestion or contact with the contaminated soil, food chain (soil-plant-humans), drinking of contaminated ground water, reduction in food quality via phytotoxicity, reduction in land usability for agricultural production causing food insecurity, and land tenure problems.[3-5]

MATERIAL & METHOD

Sarubera is a colliery of Central Coal Field limited, a subsidiary of Coal India Limited. It is surrounded by Ara Colliery of CCL from one side, Tata Colliery in the West Bokaro Zone and Tata Project site from the other side. Sarubera Colliery has underground (UG) as well as open

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cast mines. Soil sample from the over burden dump area and the adjacent agricultural site 5 km away was collected and were analysed for the presence of heavy metals. Atomic Absorption Spectrophotometric Method was used to analyze the soil samples.

RESULT

Organic Carbon matter in coal leached soil was found to be 0.61% whereas organic carbon in Agricultural Soil was 5.99%. Cation exchange capacity of Agricultural Soil was 67.21% and 28.32% in Coal leached soil. Iron content in the Agriculture Soil was 4968 mg/kg. Coal leached soil 4830.5 mg/kg. Among the heavy metals Mercury was found to be 1.25 mg/kg in Coal leached soil and 1 mg/kg in Agricultural Soil. Lead was found to be 24.5 mg/kg in Coal leached Soil and 12.5 mg/kg in Agricultural Soil. Arsenic was found to be 3.5 mg/kg in Coal leached and 2.5 mg/kg in Agricultural Soil, Copper was also found to be 13.05 mg/kg in coal leached soil and 7.5 mg/kg in Agricultural soil. Chromium was 3.85 mg/kg in Coal leached soil and 2.55 mg/kg in Agricultural soil. Level of Strontium was found to be more in agricultural as well as coal soil. However, in the coal soil its concentration was more i.e., 29.5mg/kg and in agricultural soil it was 12.5mg/kg (Table1). Cadmium in both Agricultural soil and coil leached soil was <0.5 mg/kg.

Table 1- Comparative value of different parameters in both Coal and Agricultural Soil

SL.NO.	LOCATION	PARAMETERS									
		Cr. (mg./kg.)	Fe. (mg./kg.)	Cu. (mg./kg.)	As. (mg./kg.)	Pb (mg./kg.)	Sr. (mg./kg.)	Cd. (mg./kg.)	Hg (mg./kg.)	Organic Carbon(%)	Cation Exchange Capacity(%)
1	AGRICULTURE SOIL	2.55	4968	7.15	2.5	12.5	18	<0.5	1	5.99	67.21
2	COAL LEACHED SOL	3.85	4830.5	13.05	3.5	24.5	29.5	<0.5	1.25	0.61	28.32

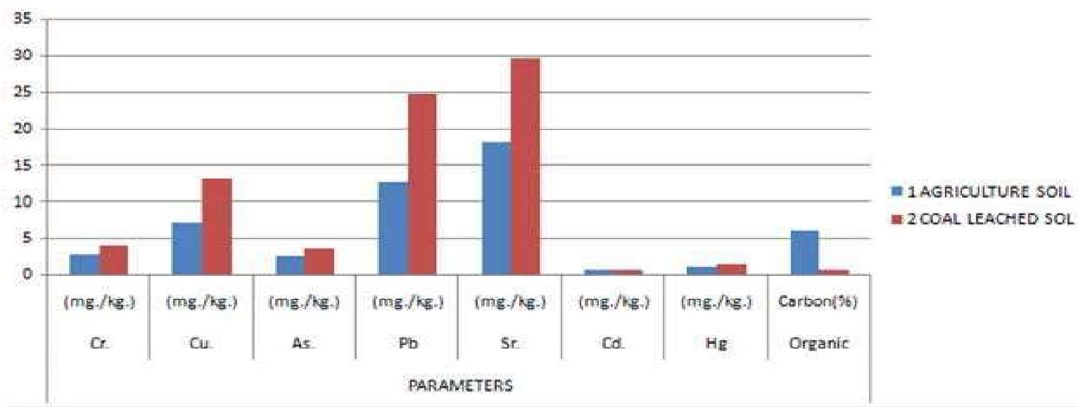

Fig. 1- Comparative Analysis of Heavy metals and Organic carbon in Coal Soil and Agricultural Soil

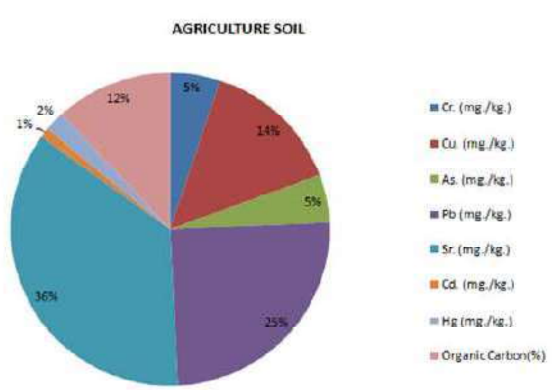

Fig. 2- Concentration of Heavy metals and Organic carbon in Agricultural Soil

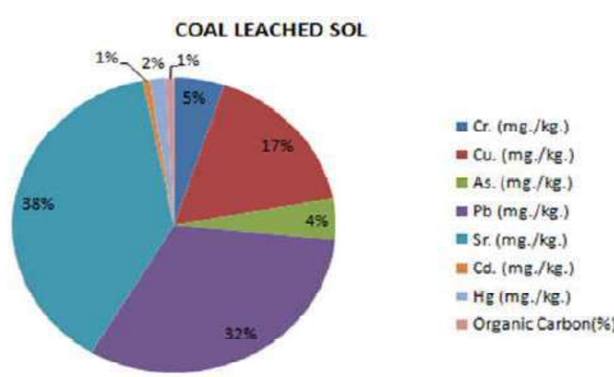

Fig. 3- Concentration of Heavy metals and Organic carbon in Agricultural Soil

DISCUSSION

Coal mining activities is a major source of contamination by heavy metals. Presence of these heavy metals determines the level of pollution and access its risk on the environment.[6] Heavy metals concentration between soils from coal mines and soils from agricultural soils were analysed. Presence of heavy metals in soil may cause carcinogenic and mutagenic effects, which pose severe threats to the health of animals and humans exposed to the soil environment.[7]

In plants Iron is essential for various processes like photosynthesis, chloroplast development and chlorophyll biosynthesis.[8] The appearance of iron toxicity in plant is related to high Fe^{2+} which causes free radicals production that impairs cellular structure and damages membrane, DNA and proteins.[9] Appropriate content of (Fe) Iron in plant is essential to both the plant metabolism and nutrient supply to humans and animals. The plant ability to absorb Fe is variable and is affected by changing conditions of soil.[10] The permissible level of iron in the soil is 425.5 mg/kg. Iron content in both the agricultural and contaminated soil was found to be more (Table 1)

Lead is one of the most abundant toxic elements in the soil. Amount of lead was almost double in coal soil than in agricultural soil (Table 1) The level of lead in both Coal soil and in agricultural soil was found to be more than the permissible level allowed by WHO. Lead affects the plant morphology, growth and photosynthetic processes. It is known to inhibit seed germination.[11] Inhibition of root and stem elongation and leaf expansion was also reported in *Allium* species.[12] Higher level of lead in soil causes various morphological abnormalities in many species. Eg– Lead cause irregular thickening in pea roots, cell walls of the endodermis and lignifications of cortical parenchyma.[13] Lead also induces proliferation effects on the repair process of vascular plants.[14]

Reduction in germination percentage, suppressed growth, reduced plant bio mass; decrease in plant protein content has also been noticed.[15] In Portia tree (*Thespesia populnea*). Reduction in number of leaves and leaf area with reduced plant height.[16,17]

Strontium in its stable form is not toxic to plant. It negatively impact the uptake of some nutrients especially Calcium by plant.[18] Higher concentration of this element inhibits the growth of soybean seedling.[19] A very high concentration of Strontium was reported in the coal soil. Level of strontium in agricultural soil was also quite high (Fig. 2,3).

Arsenic is a metalloid that occurs in a wide variety of minerals mainly in the form of As_2O_3 and can be recovered from processing of ores containing mostly Cu, Pb, Zn, Ag and Au – It is also present in the ashes from coal combustion. Arsenic is often present in anionic form, it does not form complexes with simple anions such as Cl^- and SO_4^{2-}. In humans, Arsenic is associated with skin damage, increased risk of cancer and problems with circulatory system.[20] Decreased leaf fresh weight and reduced fruit yield was reported in tomato (*Lycopersicon escultentum*) due to arsenic. Whereas in Canola (*Brassica napus*) arsenic causes stimulated growth, chlorosis and wilting.[21] Further, arsenic in rice (*Oryza sativa*) reduces seed germination, decrease in seedling height, and reduces leaf area and dry matter production.[22,23] The level of Arsenic in the coal soil and agricultural soil were found to be quite high than the permissible level which draws the concern.

Addition of mercury in the soil is due to coal combustion, as part of fertilizers, lime, sludges and manures.[17] The permissible level of mercury in the soil is 0.03mg/kg. Level of mercury was found to be same in agricultural as well as coal soil and was more than the permitted limit. After release to the environment Hg usually exists in mercury (Hg^{2+}) mercurous (Hg_2^{2+}), elemental (Hg^0) or alkylated form (methyl /ethyl mercury). Alkylated forms of mercury are more toxic as they are soluble in form and volatile in air.[24] Mercury II forms strong complexes with a variety of both inorganic and organic ligands, making it vet soluble in oxidized aquatic system.[21] Hg^{2+} in its higher level is strongly phototoxic to plant cell. It can even induce visible injuries and physiological disorders in plant.[25] Hg^{2+} induces leaf stomata closure and physical obstruction of water flow in plants by binding to water channel proteins.[26]

Higher level of Hg^{2+} interfere the mitochondrial activity and induce oxidative stress by triggering the generation of ROS (Reactive Oxygen Species). This leads to the disruption of bio membrane lipids and cellular metabolism in plants.[27] Excess of Hg^{2+} decreases plant height, reduces tiller and panicle formation yield reduction and increase of its bio accumulation in shoot and root of seedling in *Orzya sativa.*[28,29] Similarly reduced plant height, reduction in flowering and fruit weight, reduced germination and chlorosis appear on entire plant in *Lycopersicon* *esculentum.*[30] Plants differ in their ability to take up Hg and can develop a tolerance to its high concentration when grown in contaminated soil.[31]

The level of chromium in the agricultural and coal soil was almost double than the permitted level has raised the brows as severe damage in plants and animals can be caused by chromium. Damage to cell membrane due to induced chromium oxidative stress involving induction of lipid peroxidation in plants can be caused. Oxidative stress induced by chromium initiates the degradation of photosynthetic pigment causing decline in growth disturbed chloroplast ultra structure by disturbing the photosynthetic process can develop by high chromium concentration.[32] Chromium stress is one of the important factors that affect photosynthesis in terms of CO_2 fixation, electron transport, and photo phosphorylation and enzyme activity.[33]

The major metabolic stresses induced in plant due to chromium stresses are:-

(i) Alteration in the production of pigment, which are involved in the life sustenance of plants (eg- chlorophyll and anthocyanin).[34]

(ii) Increased production of metabolites (glutathione, ascorbic acid)

(iii) Alteration in metabolic pool to channelize the production of new bio chemically related metabolites, which may cause resistance or tolerance to Cr stress (eg- phytochelatins, histidine).[35]

For the normal growth and development of plants micro and macro nutrients are needed by plants. Copper is needed in trace amount by plant and is considered as a micro nutrient. Amount of copper present in the coal soil was a bit higher than the permitted level. This copper plays an important role in CO_2 assimilation and ATP synthesis.[36,37] Copper is an essential component of various proteins like plastocyanin of photosynthetic system and cytochrome oxidase of respiratory electron chain.[38] A large amount of waste rocks and tailings are generated because of mining activities which get deposited on the surface. Excess of copper in the soil plays a ctytotoxic role, it induces stress and cause injury to plants. This leads to plant growth retardation and leaf chlorosis.[39,40] Exposure of plants to excess Copper generates oxidative stress and ROS.[41] Oxidative stress causes disturbance of metabolic pathway and damage to macromolecules.[42,43]

Cadmium is one of the heavy metal poisons present in the soil. In its compounds Cadmium occurs as the divalent Cd (II) ion[5] Application of agricultural inputs such as fertilizers, pesticides sewage sludge, disposal of industrial wastes or deposition of atmospheric contaminants increase Cadmium concentration in soil. In agricultural soil the permissible limit of Cadmium is 1000mg/kg.[44] Plants growing in high level of Cadmium show injury in terms of chlorosis, growth, inhibition, browning of root tips and finally death.[45-47] Cadmium has shown to interfere with the uptake, transport and use of several elements (Ca, Mg, P and K) and water by plants.[48] It also reduces the absorption of nitrate and its transport from root to shoot by inhibiting the nitrate reductase activity in the shoot.[49] It produces alteration in the functionality of membrane by inducing lipid perioxidation and disturbance in chloroplast metabolism by inhibiting chlorophyll biosynthesis and reducing the activity of enzymes involved in CO_2 fixation.[50,51]

Metal toxicity can affect the plasma membrane permeability causing a reduction in water content particularly Cadmium has been reported to interact with water balance.[52] Cadmium also reduces the absorption of nitrate and its transport from root to shoot by inhibiting the nitrate reductase activity in shoot.[49]

Organic carbon content in agricultural soil (12%) was considerably high as compared to coal soil (Fig. 2,3). Soil organic carbon is the organic carbon content of soil. It consists of dead biotic material derived from biomass and soil biota. Soil organic carbon remains concentrated in the topsoil with the primary source from vegetation.[53] The Soil Organic Carbon (SOC) stock is severely affected by the exploitation of opencast coal mines. The influence factors of SOC stock in reclaimed lands in opencast coal mines are unclear and the existing models can not characterize the complex relationship of SOC stock sufficiently.[54]

Cation Exchange Capacity of agricultural soil was found to be more than coal soil. Cation exchange Capacity is the number of cations retained on the soil particles gives the, measure of Cation Exchange Capacity.[55] On the surfaces of soil particles the negative charges bind to the positively charged atoms or molecules. These negatively charges also exchange with other positively charged particles in the surrounding soil water.[56] It is a method by which the solid materials in the soil alter the chemistry of the soil. Cation Exchange Capacity indicates of the soil to retain several nutrients like K^+, NH^+_4, Ca^{2+} in available form.

It also indicates the capacity to retain pollutant cations Eg Pb^{2+}. Near the soil surface where the organic matter content in highest CEC is also highest. It declines with depth.[57] The interaction between the positive and negative charge of soil surface helps in absorption of cations. They retain a shell of water molecules and do not form direct chemical bonds with the surface.[58]

CONCLUSION

Soil composition in both the mining and agricultural site has been affected by the coal mining procedures. Introduction of heavy metals in the soil due to this mining activity is a matter of concern as it has deleterious effect on plants, animals and the humans living in that area. The level of most of the carcinogenic heavy metals like Arsenic, Cadmium, Lead, Mercury were found to me quite higher than the permissible level. Mining activity as adversely affected the agricultural land as well. Amount of most of these heavy metals were also found to be more in the agricultural soil than the permitted level. Plants uptake these heavy metals from the soil and from the plants these hazardous heavy metals is taken by the animals. This is how these carcinogenic metals enter the food chain and cause biomagnifications. Growth of plant is badly affected by these heavy metals. It also cause various chronic diseases in animals and humans.

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