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APPLICATION OF SOIL-PLANT-MICROBE INTERACTIONS FOR ECO-RESTORATION OF HEAVY METAL CONTAMINATED MINING SITES - A REVIEW

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ABSTRACT

Mining industries are known to generate various dangers and risks that endanger biological communities worldwide. The heavy metal mobilization by extraction from ores and various anthropogenic activities for various functions is held responsible for these elements being discharged into the environment posing a great risk to ecological health and human wellbeing. The extensive mining activities causes yield reduction, erosion and disruption of soil surface and human ill-health. Mine waste management practices as per eco-restoration, phytoremediation or bioremediation methods has indicated amazing results in various mine locales, either coal or other mineral mines. This review aims to study prospects of Reclamation of currently mined land to an acceptable form and planned use. Various aspects of the environmental rebuilding and recovery on dumped mine sites which is important for sustainable development. Efficient planning and environmental management can ensure minimized effects of mining on the earth and hence help safeguard the ecosystem.

Keywords: Acid Mine Drainage, Bio-remediation, Eco-restoration, Heavy Metal, Mining industries

I INTRODUCTION

Mining industries are known to pose threat to the natural environment and risks that endanger biological communities worldwide [1]. Mining operations and their unscientific waste transfer strategies are thought to be the primary source of heavy metal pollution in soil, water (ground & surface water) and deforestation. The two major types of mining i.e., opencast and underground mining are causing damage to the natural ecosystems. Especially, opencast mining results in removal of the overlying soil and the fragmented rocks are heaped as overburden (OB) dumps [2] ultimately leading to degradation of abandoned mine sites. About 90 % of the mining wastes from the extraction of metals are in the form of sulfides and these squanders contains high amount of heavy metal toxicity particularly Cu, Zn, Cd and Pb [3]. Although metals are also useful resources for the healthy environment, but at high concentration it leads to environmental degradation [4]. The study aims at recovery of mined out area to an acceptable form and to counteract negative effects to soil, water and air assets in and around the mined zones, re-establish the quality of the soils to their premining level, enhance surroundings and utilitarian quality. Eco-reclamation as indicated by USDA is characterized as, the revival of a biological system to a nearby estimate of its normal condition before unsettling influence. The objective is to imitate a characteristic working, automatic framework that is coordinated with the biological system. The re-established biological system ought to mimic the regular condition before it was harmed. It must be stable with negligible human contribution after the underlying endeavours that may include hastening the rate of progression, returning to a prior stage, or changing the direction of progression. It incorporates the identification, evacuation, stockpiling and substitution of soil materials, and re-vegetation.

The remediation of the soils contaminated with heavy metal poses number of difficulties. At international level various modern-day technologies are being used to clean the metal contaminated soils [5] but either they offer a temporary solution, are time consuming, environmentally destructive and disturbs soil native microflora or immobilize the metals or are not economically feasible when applied in expansive scale. The modern day bio-technological clean-up methods are found to be a successful hotspot for heavy metal remediation from soil [6]. It is established that the harmful effects of metals is responsible for changed physiology of plants including restrained root development, photosynthesis [7], cell division and genotoxicity in plants [8].

Mine waste management practices as per eco-restoration, phytoremediation or bioremediation methods has indicated amazing results in various mine locales, either coal or other mineral mines [9]. Phytoremediation is an indispensable tool box for wider application in the realm of environmental protection. Phytoremediation is the utilization of plants and related soil microorganisms to minimize the number or poisonous impacts of toxic elements in the environment [10]. It is an effective alternative to high-cost, energy demanding conventional methods, has aesthetic advantages and long term applicability and hence thought to be a “Green Revolution” in the field of innovative remediation technologies.

II POLLUTION DUE TO HEAVY METALS AND SOME TRACE METALS

The land near the coal mining area has heavy metals in abundant in soils. Dissolution of heavy metals from coal takes place at low pH in that area. According to Environment Protection Agency (EPA), the eight most common heavy metal pollutants are As, Cd, Cr, Cu, Hg, Ni, Pb and Zn. Though some heavy metals are necessary for human growth and development, in higher concentration they cause antagonistic consequences for human wellbeing. The ecological problem of water and soil heavy metal contamination is of great importance in today’s global scenario. The contamination of soil with heavy metals from seepage can potentially result in phytotoxicity [11]. In general, heavy metals attack the active sites of enzymes repressing essential enzyme function. Heavy metal ions particularly Hg^{+2}, Pb^{+2} and Cd^{+2} act as viable enzyme inhibitors. They can break the sulphur hydrogen bonds of enzymes

III IMPACT OF MINE WASTES/METALS ON ENVIRONMENT

The assessment of impact of soil pollution in the near-by areas of large mine and industrial waste disposal sites is difficult and it is dependent basically on pattern of land use, kind of soil, agro-climatic conditions, vegetation population characteristics and nature of contaminants [12]. Soil is a basic natural resource that should not only be preserved but where ever possible also improved [13]. Acid Mine Drainage (AMD) deteriorates soil's physical and chemical properties and thereby adversely affects crop growth and yield. Major impacts of Acid Mine Drainage on soil include soil acidity [14] and contamination of soil with heavy metals [15]. Irrigation of agricultural fields with AMD contaminated water also causes various problems, which altogether decrease agricultural productivity.

Heavy dump of mine wastes disrupts the soil ecosystem; especially the aerobic microbial population [16]. Metal ions from metal mines, cause serious stress to the natural surroundings (acidification) by discharging mined water from mines. Leachate water and spill over water from OB waste dumps additionally debase adjacent water systems. Potential health hazards for humans caused by these toxic metal ions also affect other life forms through soil and water pollutions. It has been suggested that low nutrient levels, low water availability, metal toxicity, acidity and poor physical structure of mine and adjacent soil, will reduce the vegetation on the site [17] through soil erosion [18]. Another reason that mine spoils are generally nutritionally and microbiologically poor is that mining activity results in the loss of topsoil, which is an integral exchange and storage site for nutrients [19]. Besides, mining is one of the major contributors of soil erosion due to loosening of soil and increasing vulnerability of loosened soil to water and wind erosion.

3.1 Impact on forest, animals and human

Mining being a transient activity has long haul impacts. No doubt that when it happens in forested areas, it leads to degradation and deforestation, forest soil erosion, geo environmental disasters and biodiversity loss [20]. Despite government of India’s policy in relation to reclamation and rehabilitation of abandoned mines, it is estimated that, including oil extraction, mining is threatening 38% of the remaining extends of the world's essential forests [21]. Expanded sediment loads (heaped top soil) and water streams can genuinely influence local biodiversity and structure, such as frog, nematode community [22], soil and water reptiles populations. In addition, it is also noted that the DNA damage is possible in earthworms present in metal polluted soil [23]. The heavy metals could cause physico-mental discomfort and often life-threatening diseases including irreversible damage to vital body systems [24]. The heavy metals have been held responsible for causing deadlier diseases like, tumour, pharynx, [25] gastrointestinal, reproductive, neurological, hereditary breakdowns and disruption of metabolic functions [26]. The metals directly or indirectly cause the DNA damage of living things, increasing the risk of cancer [27], nerve cell damage and reproductive disorders [28].

IV APPROACHES FOR METHOD OF CONTROL

Globally several approaches have been followed for remediation process on heavy metal laden soils. They are broadly classified into two types.

4.1 Physical & Chemical approach

These represent the most diverse group of remediation processes. Physical approach includes soil vapour extraction, solidification/stabilization [29], soil flushing [30] and electrokinetic separation [31]. The primary chemical approach is oxidation, by using various chemicals such as sodium or potassium permanganate [32], fenton's catalysed hydrogen peroxide [33], ozone and sodium persulfate. The cost required for these physical and chemical treatments on waste soil/ton is 75 – 500 dollars [34].

4.2 Biological approach

The biological treatment (bioremediation) approach includes the utilization of organisms to detoxify and degrade ecological contaminants has received increasing attention in recent years to treat the polluted environments [35]. The *Acidithiobacillus* group of bacteria is in-charge of the disintegration and activation of toxic metals in acidic environment created from surrendered mines, mine waste and tailing dumps [36]. Another biological treatment is phytoremediation, a potential cost effective technology for the contaminated soils [37] by using plants. The plants absorb, accumulate and detoxify the contaminants in metal contaminated soils. This technology is eco-friendly while prevents landscape destruction, enhances the activity and diversity of soil microorganisms to maintain healthy ecosystems. The plants suitable for phytoremediation ought to have a high biomass with enhanced metal tolerance and metal sorption potential [38]. The biological treatments are very efficient, cost effective (5 – 40 dollars/ton) methods than physical & chemical methods, for removing the metals at lower concentrations [34].

4.2.1 Microbes in mine soil

The microbes present in the contaminated mine soils shapes a fundamental premise to comprehend the possibilities of natural recovery outcomes, since they are critical for enhancing the nutrient accessibility in soils for growth of the plant and development of native soil inhabitants [39]. Natarajan [36] reported several species of bacteria i.e. *Acidithiobacillus ferrooxidans, A. thiooxidans, Thiomonas sp., Leptospirillum ferrooxidans and Desulfotomaculum nigrificans* isolated from mine waste dumps from Bangalore (Karnataka). Similarly, *Pseudomonas, Bacillus, Aerobacter, Caulobacter* and *Staphylococcus* were isolated from spilled mines [40] and the effective conservation and use of microbial diversity in mine soil was reported by Kalia and Gupta [41]. Recently three bacterial groups (chemolithotrophic, acidophilic and thermophilic) were isolated from coal mine soil at northern part of India [42].

4.2.2. Bioremediation

Bioremediation of heavy metal sullied soils is a characteristic clean-up process by micro-organisms (fungi and bacteria). Sulfate-Reducing Bacteria (SRB) and facultative methylotrophic metal-tolerant sulfate-reducing microbes are for the most part utilized for acid mine seepage treatment and metal contaminated soils [43]. In India, the heavy metal contained mine dirts have been dealt with by utilizing microbes, for example, *Thiobacillus ferrooxidans, T. thiooxidans, T. acidophilus, T. neupolitanus, T. thiopams, Metallogenium sp*. and *Leptospirillum sp*. Etc. Further, another bacterial species from the genera like *Bacillus, Escherichia Enterobacter,* and *Pseudomonas* were utilized for compelling bioremediation of metal polluted soils [40]. The fungi *Aspergillus niger, A. fumigatus, Penicillium sp, Rhizopus sp, Mucor sp, Trichoderma sp.,* are being viably utilized for the remediation of mine/metal sullied soils.

4.2.3. Heavy metal impact on crops/plants

Higher plants are known induce reactions to heavy metals in their surroundings which meddle with the hereditary constitution of plants [44]. Adaptive response is one of the essential procedures that plants inalienably react, keeping in mind the goal to withstand adverse conditions presenting genomic security. Among the higher plants, horticultural yields have noteworthy capacity to move metals in their tissues, known as great bio-indicators and assume a key part in detecting metal harmfulness and resistance. Pandey et al. [45], reported the heavy metal (Co, Ni, Zn, and Cd) prompted oxidative harm and changed oxidative reaction on plants (Spinach) and studied heavy metal impelled DNA changes in aquatic macrophytes utilizing RAPD examination.

4.3. Phytoremediation

Phytoremediation is a biological technique to reduce, degrade or immobilize the environmental pollutants (inorganic compounds) using crops/plants. The procedure is a financially savvy, non-intrusive and socially satisfactory approach to address the evacuation of natural contaminants. It delivers intact, biologically active soil. The idea of using plants to extract heavy metals from contaminated soils was reintroduced and developed by Chaney [11]. In India, several plant species viz. *Paspalum, Eriochloa, Helianthus, Pennisetum Juncus, Scirpus, Brassica juncea, Vetiveria, Sesbania, Scirpus, Thymus, Ammania baccifera* and *Scleranthus* are used for phytoremediation process on heavy metal contaminated mine soils [46]. The fodder species is an effective accumulator of metal and which shows accumulation of metal when exposed to stress [47]. The assessment of heavy metal bioaccumulation efficiency of *Eisenia sp, Cynodon dactylon* and *Vigna radiata* in soil systems contaminated with multiple metals were investigated by Rathi et al. [48]. Dutta and Agrawal [49] have studied the tree plantation and reclamation experiment on waste soil of coal mine. One recent report stated that *Cajanas cajan* is a moderate agent for heavy metal accumulation from mine spoil [50]. Some molecular level phytoremediation approach was conducted by Goel et al. [47] for remediation of metal polluted soil using *Alyssum lesbiacum* and *Nicotiana glauca*, a fast-growing high-biomass plant, which could survive on mine soil.

4.3.1 Phytoremediation using genetically modified plants

Both microbes and higher plants have been hereditarily adjusted for detoxification of soils debased with heavy metals. (i) Transgenic of *Arabidopsis thaliana* were developed for decontamination of soils toxified with either aluminum, or arsenic or mercury; (ii) *Ralstonia eutropha* was transformed utilizing gene encoding metallothionein from mouse, expressed on the surface of the cells helping in extraction of cadmium from the soil. For aluminum detoxification, a gene encoding citrate synthase (CSb) was utilized, while for arsenic, gene encoding arsenic reductase (ArsC) and glutamylcysteine synthase (gamma-ECS) , for mercury detoxification, gene encoding mercury reductase and organomercurial lyase (merA and merB) were utilized [51].

The most critical proteins included in aggregation of metals and rendering resilience are PCs (phytochelatins) and MTs (metallothioneins) [52]. PCs are little glutathione-determined, formed by activity of enzyme phytochelatin synthase which binds to metals and are essential part of the metal detoxification framework in plants [53]. MTs are gene encoded, low atomic weight, metal-binding proteins, which can ensure plants protection against the impacts of poisonous metal particles [20]. By over articulation of common chelators (PCs, MTs and natural acids) metal ions' passage into plant cell as well as translocation through xylem is encouraged [54].

V CONCLUSION AND RECOMMENDATIONS

It is not so distant in the future that there will be a tremendous burden on mining commercial enterprises to deal with the waste generated due to foul mining practices. In India, Coal mines generate extensive amount of waste as Over Burden dump negatively influencing the environment. Re-handling of wastes containing heavy metals should be given accentuation from ecological and wellbeing contemplations as well as a resource preservation measure. Reduction of mine waste may be a decent approach for mine waste administration. Such kind of mine waste decrease might be conceivable by utilizing this waste in public sectors as building materials or utilizing this waste as a part of mine inlaying. Advancement of vegetation according to eco-restoration is a standout amongst the most suitable and simple part of mine waste management. Juwarkar et al. [55] have studied the potential of re-vegetation for development of sustainable ecosystems on mine soil dumps. It is environment friendly and also, cost effective. Phytorestoration upgrades biological capital and gives biodiversity suitable to the area where such rebuilding measures are attempted. Role of native species in recovery requires a watchful thought as recently presented intriguing species might prove to be nuisances in different circumstances. These desired species for vegetation are ought to be screened painstakingly to abstain from getting to be dangerous weeds in relation to neighborhood native flora. Indigenous species are desirable over exotics in light of the fact that they are well on the way to fit completely into active biological community and are climatically adjusted [11]. Mining associations are building up the ability to bring together the species that have opportunity to develop, create, and remake the neighborhood biodiversity.

The result of eco-reclamation relies on plant distribution pattern after rebuilding of the sites. In this way, the record of biological progression and procedures is imperative to demonstrate the achievement of eco-reclamation [56]. Moreover, the general challenge of eco-rebuilding is in developing a technique which is sitespecific, as all sites around the globe are not alike. Recovery of OB dumps is not an operation, which ought to be viewed as just at, or just before closure of mine. But, it ought to be a part of an incorporated project of a powerful ecological management through all periods of resource improvement - from investigation to development, operation, and conclusion. Great management and ecological administration will minimize the effects of mining on the earth and will help in protecting eco-diversity.

The accompanying Suggestions can be utilized for further action:

i. Reusing/reprocessing of waste containing harmful metals should be given more noteworthy accentuation from ecological and wellbeing contemplations as well as a resource preservation measure.

ii. Observing of air, water and soil in the region of the harmful metal processing units should be completed all the more thoroughly for the particular metal.

iii. Tailings dumps and process squanders lying in areas near the metal processing units should be remediated at earliest.

iv. Rules for appropriate administration of tailings and slags containing dangerous metals ought to be arranged thinking about techno-financial attainability and checking of well-being of labourers occupied with the handling of dangerous metals/mines ought to be done frequently.

v. Periodic checking of the site for bare spots, eroded areas, areas of excessive settlement and other areas where initial attempts to establish vegetation were not successful and periodic soil testing and checking of vegetation to determine if additional soil amendments are needed.

"**We did not inherit the Earth from our Ancestors, but borrowed it from our Children**". This Native American proverb being an eye-opener, rightfully acknowledges the change we need to bring in for sustainable growth and development. Their future must be considered, before looting the earth and tainting it mercilessly.

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