iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 **Issue:** IX **Month of publication:** September 2021

DOI: https://doi.org/10.22214/ijraset.2021.37394

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue IX Sep 2021- Available at www.ijraset.com

Reclamation of Abandoned Mine Soil: A Review on Properties and Remediation Techniques

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Abstract: The environment which is a part of ecosystem is being polluted due to urbanization, rapid industrialization increased demands for resources in our day to day lives have left no resources untouched. Various anthropogenic activities such as mining and milling operations, which include grinding, screening, concentrating ores and removal of tailings, disposal of mine and mill waste water release toxic metals into the natural environment affecting the lithosphere. Reclamation is the process of restoring the environmental soundness of these distressed mine lands. It consists of governing all kinds of physical, chemical and biological inconvenience of land area or soil such as fertility, pH, microbial activities and different soil nutrient cycles that make the destructed land soil fertile. The main aim of the reclamation is to bring back the fertility of soil by increasing its N, P, K values and Carbon contents. There are various remediation technologies available for removal of heavy metal from contaminated mine soil, in this paper we have discussed in-situ remediation, physical remediation, chemical remediation and biological remediation technologies which are implemented across the globe.

I. INTRODUCTION

Abandoned mine soil has become curse to the ecosystem. The rate of consumption and exploitation of mineral resources is persistently growing with the progress of science and technology, economic upswing, industrial augmentation, advancement of urbanization and community expansion (Kundu and Ghose, 1997). Soil in the abandoned mines has high levels of heavy metals due to various mining and milling operations. The major sources of heavy metals which contribute in soil contamination are via., mining the metal, foundries, smelting operations, metal leaching from various sources, and other milling operations which include grinding, screening, concentrating ores, removal of tailings, disposal of mine and mill waste water (Faramarz Jalali, 2007).

Most common heavy metals found at contaminated sites are arsenic (As), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), ferrous (Fe), lead (Pb), manganese (Mn), mercury (Hg), nickel (Ni), tin (Sn), zinc (Zn), etc. Soil gets greatly affected by those heavy metals that are released into the environment by anthropogenic activities. Unlike organic contaminants which are commonly oxidized to carbon (IV) oxide by various microbial actions, many of these metals does not undergo microbial or chemical degradation (T.A. Kirpichtchikova et al, 2006). Thus, the total concentration in soil remain longer period of time (D.C. Adriano, 2003). It has been reported that there are more than a million of abandoned mines across the world. In India there are several abandoned mines which are not reclaimed. During a special study at nationwide in April 2003, 297 abandoned sites were recognized. Out of which 106 sites belong to public sector which requires rehabilitation. 24 sites out of 106 can be operational for the second time, remaining 82 abandoned sites require reclamation and rehabilitation (Indian Bureau of Mines, 2003). The number of abandoned mines in different states are compiled in Table 1. Madya Pradesh has maximum number of abandoned sites.

Table 1: list of 82 abandoned sites for recovery

States	Number of Abandoned Sites
Andhra Pradesh	12
Goa	1
Gujrat	1
Jharkhand	8
Karnataka	2
Madhya Pradesh	34
Maharashtra	2
Orissa	4
Rajasthan	2
Tamil Nadu	12
Uttar Pradesh	1
Uttarakhand	3

Table 2: abandoned mine problems

Problems	Results
Accumulation of explosive gases	Lack of circulating air in galleries, unsafe structures, accidents, fires.
Removal of top soil	Erosion, unproductive for plant and animal life, unsafe land patterns, alteration of fauna
Soil and water contamination	Heavy metals risk through food chain, ground water contamination, lack of soil fertility, food production.
Deforestation	Removal of vegetation, hazard to habitat, risk to plant and animal life.
Air Pollution	Respiratory problems and other health hazards.
Climatic Conditions	Change in local rainfall, temperature, humidity, wind speed.
Migration of local people	Local people move away from the site due to health hazards, pollution.

Abandoned mines pose serious threats to the ecosystem, degrading air, water and soil. they also cause socio-economic problems they can regulate local climatic conditions (Table 2)

A. Soil Factors/ Properties Ecologically Worsening The Abandoned Mine Area

Soil properties like aggregation, compaction, topography, pH, fertility, microbiome decide the degree of damage in the ecosystem. Here we discuss various physical, chemical, and biological properties of abandoned mine soil

1) Physical Factors/ Properties

a) Coarse Aggregate: Soil particles having size smaller than 2mm are important for holding the majority of water and nutrients in mine soil. The soil particles of size greater than 2mm are called as coarse aggregates and are not suitable to hold required amount of water to the plants as they contain large pores. Most of the water gets leached down and cannot supply enough water to plants during summer. The contents of the coarse aggregates in mine waste vary (< 30 % -> 70%) due to difference in hardness of rock, blasting methods and also waste handling techniques. The parent rocks or spoils inherit the particle size distribution to the mine soil directly. The rock contents in the reclaimed soil get reduced due to weathering of rocks into soil particles (Nicolau, 2002; Moreno-de las Heras et al, 2008). Hu et al, 1992, states that soil that consists of stone fragments higher than 50% must be considered as poor quality. Stone fragments of coal mine wastes have been reported to be as high as 80%-85 % (Maiti and Saxena, 1998).

b) Soil Texture: The soil texture is determined by the presence of relative amount of clay (< 0.002 mm), silt (0.05 - 0.002 mm) and sand (2.0 - 0.05 mm) sized particles. Fine textured loamy and silty soil can hold more water and nutrients compared to sandy mine soil. The silty soil is fine graded and has susceptibility to form surface layer, containing high amount of soluble salts and have a weak “tilth” or consistence. The loamy textured soil has ideal particle size distribution generally. The mine land having siltstones normally contains silt loam textured soil in dominance (Ghose, 2005). Ghose, 2005, reported the maximum of 66% sand and 8.6% of clay in mined soil. The maximum content of sand (80%) and of clay (11%) is observed at the Singrauli Coal field India as reported by (Singh et al, 2006).

Table 3: properties of soil texture

Soil type	Particle size	Reference
Clay	< 0.002mm	Ghose, 2005
Silt	0.05-0.002mm	
Sand	2.0-0.05mm	

c) *Soil Aggregation:* The aggregation of the soil controls soil hydrology; affect soil distribution and the grade of nutrient availability to the soil (Lindemann et al, 1984; Heras, 2009), and may decrease erosion possibility (Elkins et al, 1984) and contains a trail of organic carbon equalization and stable isolation (Six et al, 2004). Aggregate structure is broken down as consecutive layers of soil are removed and accumulated somewhere on the mine site during the commencement of the mining. The proceeding compaction hinders water storing capability and aeration. Large sized aggregates stability is mainly responsible for larger porosity, which influences soil percolation rate and aeration. It changes seasonally and is frequently affected by agriculture and cropping routine (Kay, 1990). The strength of micro aggregate is more resilient than macro ones, as the organic substances required to shackle the soil fragments together lie in pores which are too small for the microorganisms to get settled in (Gregorich et al, 1989). The micro aggregates are less susceptible to farming mechanisms than macro aggregates (Dexter, 1988) and they are in charge of trace porosity which manages the quantity of water accessible for foliage (Davies and Younger 1994).

d) *Moisture, Bulk Density, Compaction and Available Rooting Depth of Soil:* The moisture content of the mine soil is a varying factor as it depends on the time of sampling, stone particles, height of dump, organic carbon quantity and the thickness and texture of the junk layers on the land surface (Donahue et al, 1990). During the winter season, the average water content is found to be sufficient for plant growth as it was about 5%. During the high summer time, the moisture content falls to 2-3% as reported (Maiti et al, 2002) as reported by Maiti and Ghose, 2005, the average field moisture of all mining dumps was 5%. Bulk density of fertile natural soils normally ranges between 1.1 to 1.5 g/cm^3. As the bulk density increases it decreases the rooting capacity of the soil. Bulk density of the soil under a grass sward in UK was found to be as high as 1.8 Mgm-3 as reported by Rimmer and Younger, 1997. Soil compaction directly affects the vegetation, as high compaction of soil limits the plant growth as they hinder the effective extension of roots through them due to high bulk density of mine soil. Three to four feet of non-compacted loose soil is necessary for the plan growth as they hold enough water in them, even though prolonged droughts. Severely compacted mine soil (bulk density > 1.7 g/cc) especially those which are having less than two feet of effective rooting depth, presence of huge boulders in soil and shallow intact bedrock cannot sustain required amount of water to support vegetation.

Table 4: variation of moisture content

Seasons	% of Moisture	Reference
Winter	5%	Maiti et al., 2002
Summer	2-3%	

e) *Slope, Topography and Stability:* Mine land having slopes greater than 15% are normally not suitable for comprehensive land uses such as growing vegetable or farming but are suitable for grazing and reforestation. Fills with slopes less than 2% and broad, flat benches have seasonal wetness problems. Most of the benches with overall tender slopes consist of areas of enormous rockiness, hummocks, pits and ditches. Bench areas just above entire bedrock on older mined lands are generally reasonably stable but may be subject to slumping, particularly when near the margin of the out slope. Tension cracks running approximately collateral to the out slope specify that the area is unsteady and likely to sink. Decrease in soil strength can lead to increase in bulk density (Daniels, 1999), Nitrogen losses by denitrification follows such environment (Davies and Younger 1994).

f) *Mine Soil Colour:* The physical and chemical properties including weathering history of soil can be studied by the colour of mine spoils. The bright red and brown colour of the soil shows that the soil has been leached and oxidized to some amount normally. These soils tend to have low pH and free salts, and are low in pyrites less fertile, and mostly susceptible to physical weathering when compared to darker soil. The lack of oxidation and leaching, greater value of pH and fertility is represented by grey colour rocks or spoils and soils. Very dark grey and black coloured rocks, spoils or soils indicates the presence of considerable amount of organic matter and are most likely to be acidic. Dark coloured spoils absorb more solar energy and become too hot to re-vegetate during summer seasons (Daniels, 1999).

g) *Top Soil:* Mining activity remove the top layer of the earth, dumping it over an unmined area forming groups of external piles which are called as mine spoil. Mine wastes contain extreme conditions for both plants and microorganism growth. The biological services and the nutrients offered by the soil system is disturbed which leads to non-functioning soil. This is mostly caused due to low level of organic matter and unfavourable contents of physical, chemical and biological or microbial characteristics of soil (Singh et al, 1999; Jha et al, 1993; Singh et al, 2006). Top soils help in covering the poor substrate and to provide better growth conditions for plants. Accumulation of top soil in dumps during the extraction of minerals affects the physical, chemical and biological characters if the soil (Hunter and Currie, 1956; Barkworth and Bateson, 1964; Harris et al, 1989; Johnson et al, 1991; Davies et al, 1995). Top soil is a scarce asset, and it is not stored in most of the potential source. Also, in a tropical climate where 90% of the rain is percolated within three months it is challenging to store and preserve the top soil quality. It is never stored for the purpose of reuse but always it is taken from the nearer areas for reclamation of the disturbed mine lands. At a depth of about 1m in the dump, the number of aerobic bacteria gets lesser and the anaerobic bacteria gets higher (Harris et al, 1989). The accumulation of ammonia takes place in the anaerobic zones of pile due to lesser nitrification which is caused by poor aeration. Nitrification restarts and it takes place at a higher rate when the stockpile is removed and restored, as there is greater level of aerobic microorganism population which is rapidly re-established usually higher than the normal level (Williamson et al, 1991). The amount of nitrate generated would be greater than normal if the restored soil consists high amount of ammonia. Accordingly, there is a greater chance of Nitrogen loss to the environment through leaching or denitrification (Johnson et al, 1994). Nitrate leached in to the aquatic territory causes ground water pollution (Addiscott et al, 1991) as well as nitrogen lost in the form of gaseous nitrogen or nitrous oxide leads to the degradation of ozone layer (Isermann, 1994; Davies et al, 1995). The time period between the initial eradication of top soil and the final implantation of the same over the restored area might take a long-time lapse. Hence the properties of the dumped soil continuously degraded and at last become infertile if it is not preserved properly (Ghose, M.K., 2005).

II. CHEMICAL PROPERTIES

A. Soil pH

Soil pH is a most frequently used indicator to check the quality of mine soil, soil pH is measure of active soil acidity. Weathering and oxidization of the rock particles affects the pH of the soil to change rapidly. Pyritic minerals (FeS_2), which present in the mine soil, oxidizes to form sulphuric acid and exceptionally tends to lower the pH of the soil, while the presence of carbonate ($Ca/MgCO_3$) containing minerals or rocks weather and dissolve, results in the increase of pH. In the neutral pH the vegetation achieves the peerless growth. When the pH of the soils falls to 5.5, decrease in the growth of lentils and fodder occurs due to noxious metal such as Aluminium, Manganese, reduced population of Nitrogen fixing bacteria and phosphorous fixation. This development inhibits the metabolic processes and in-turn inhibits plant root growth. The mine soil having pH range 6.0 to 7.5 is suitable for fodder and other agricultural or horticultural uses (Gitt et al, 1991; Gould et al, 1996).

B. Soil Fertility

The overburden piles lack three major macro nutrients required for plant growth they are nitrogen, phosphorus and potassium normally (Coppinet al, 1982; Sheoran al, 2008). The older ones or the newly created mine soils, need to be sufficiently applied with effective amount of fertilizers for establishment and maintenance of the vegetation. The major source of nutrients such as Nitrogen potassium and phosphorous is the organic matter in unfertilized soil (Donahue et al, 1990). 0.75% and greater level of organic matter indicates sufficient fertility to support plant life (Ghosh et al, 1983). Generally, the 0.35% to 0.85% of the organic carbon is found in overburden dumps. Presence of organic carbon in mine dump positively corresponds to the presence of nitrogen and potassium while negatively corresponds to the presence of Fe, Mn, Cu and Zn (Maiti and Ghose, 2005). The initial application of fertilizers has shown the increase in the growth rate and density of the plants. Fe, Mn, Cu, and Zn are some of the important metallic micronutrient required for the plant growth. When the mixing of primary minerals takes place due to weathering of minerals continuously the micronutrients take their place in the soil. These metals form toxic concentration and inhibit plant growth as they are more soluble in acidic conditions (Donahue et al, 1990; Barcelo et al, 2003; Das and Maiti, 2006). Maiti and Ghose, 2005, reported that for the sustainable reclamation of the mine dump it is necessary to increase the pH and organic matter in soil. According to Lindsay and Norvell, 1978, the soil is highly sufficient for ecological sustainable reclamation if the soil has micronutrient levels higher than 4.5 mg kg-1 for Fe, 1.0 mg kg-1 for Mn, 1.0 mg kg-1 for Zn and 0.4 mg kg-1 for Cu. The type and concentration of fertilizer applied must be according to the site requirements such as soil type, post mining land use (Kenny and Bremner, 1966) and care should be taken while application of fertilizers as they can damage the roots of the seedlings when injected too close to the plant (Schmidt, 2003; Ghose, 2005).

Table 5: Soil Fertility to use for Agricultural Purposes

Minimum value of micronutrients required (mg/kg)	Micronutrients	Reference
4.5	Fe	Lindsay and Norvell, 1978
1	Mn	
1	Zn	
0.4	Cu	

III. BIOLOGICAL PROPERTIES

A. *Soil Microbe*

Soil microbe population is an important factor that influences the fertility of the soil. Soil microbes play a major role in stabilization of soil particles which are required for cultivation and porosity of the soil for plant growth by maintaining proper structural conditions (Ghose, 2005). The microbial activity declines as the soil gets degraded. The soil microbes consist of various types of bacteria which are essential for the decomposition of plants and other fungal species, the absorption of nitrogen and phosphorus in exchange of carbon takes place due to their symbiotic relation with many plants. They support the plant growth by the production of polysaccharides that improves the soil aggregations (Williamson et al, 1991). Soil microbes effect the soil aggregation so much that, sites with active soil microbes have stable soil aggregation which the sites with less microbial activity shows compacted and poor aggregation (Edgerton et al, 1995). The microbial activity varies with depth and time it decreases as the depth increases and time increases as the topsoil is stored during mining (Harris et al, 1989). The ATP (adenosine tri phosphatase) level goes on decreasing within few months which is used to measure the microbial activity (Visser et al, 1984).

B. *Bacteria*

When moisture levels in the soil are high, bacteria play an important role in decomposition of organic materials especially in the early stages. Fungi tend to dominate in the later stages of decomposition. Rhizobia belong to a family of bacteria called Rhizobiacea, which are single celled bacteria forms a symbiosis or mutually beneficial association with lentil plants. These bacteria convert the atmospheric nitrogen into ammonia (NH_4^+) which is used by the plants (Gil-Sotres et al, 2005). Rhizo-bacteria which is a free living and symbiotic plant growth supporting bacteria ,influences plant growth directly it provides bio-available Phosphorus for plant intake, helps in nitrogen fixation, confiscating trace elements for plant growth such as iron by siderophores, lowering of plant ethylene levels and producing hormones like auxin, cytokinin and gibberellins (Glick et al, 1999; Khan, 2005).

C. *Mycorrhizal Fungi*

Arbuscular mycorrhiza fungi are pervasive soil microbes situated in almost all climates and habitats. When the soils are moved or stockpiled the hypha network made by mycorrhizal fungi breaks down (Gould et al, 1996). It is well reported that the association of mycorrhiza with plant growth and survival and also intake of nutrients such as phosphorus, nitrogen especially phosphorus deficient dilapidate soils (Khan, A.G, 2005). The viable mycorrhizal inoculums potential decreases during the first two years of storage of stockpiles (Miller et al, 1985). When compared to undisturbed soil viability of mycorrhiza in stored soils lessen substantially to the levels of 1/10 (Rives et al, 1980). Soil water potential is a significant factor which affects the mycorrhizal viability as reported by Miller et al, 1985. Mycorrhizal propagules can survive for a greater lengths of storage time when the soil water potential is less than -2 MPa (drier soil). Mycorrhizal propagules are threatened by the deep stock piles during drier climates. Shallow stockpiles are crucial to magnify surface-to-volume ratios in concern to moisture evaporation in wetter climates.

IV. RESTORARION METHODS FOR CONTAMINATED SOIL

Reclamation is the process to retrieve the ecological soundness of the interrupted mine land areas and enhance the productiveness of the land. Reclamation includes the governance of various types of physical, chemical and biological depletion of soils such as soil pH, fertility, microbial community and various soil nutrient cycles that make the destructed land soil fertile (Sheoran.V et al, 2010). There are several remediation technologies available for removal of heavy metals from contaminated mine soil. Some of them are in-situ remediation, physical remediation, chemical remediation and biological remediation.

A. IN-SITU Remediation

Some of the in-situ methods that would be utilized to minimize the visible effect of quarries and grant plausible for the formation of biodiversity are natural recovery, rollover slopes, backfilling, bench planting, restoration blasting (Gunn and Bailey,1993; Walton et al, 2004)

1) *Natural Recovery:* Natural restoration mainly depends upon the plants, trees and seeds available in the adjoining area which will be escorted by wind, insects, birds and runoff eventually (Davis et al, 1985). Natural redemption is one of the low cost substitutes for the restoration of mine quarries (Novak, J. and M. Konvicka, 2006). The demerit of this technique is it takes long period of time to recover. Some studies show that quarries left to natural rehabilitation is rich in biodiversity and has superior view than recovered by human involvement (Cilek.V, 2006; Cullen et al, 1998).
2) *Rollover Slopes:* In this method soil is used as a filling matter to form a uniform slope over the quarry edge. This type of formation may have irregular slopes having potholes which provide a perfect environment for tiny vegetation (Cripps et al, 2004; Water-Front-Trail, 2010). This helps a wide number of herbal plants to grow in the diverse region of the restored quarry (Moffat.A and J.McNeill, 1994; Nicolau.J.M, 2003). Applications of filling matter in the quarries avoid landslides and helps in easy accessibility. Huge amount of soil or filling matter is required which is one of the major drawbacks of this technique.
3) *Backfilling:* Addition of soil, filling matter or waste material into quarry space in order to partially or entirely recover the excavated land which may lead to formation of new landscape (Haywood.S.M, 1979). This technique is broadly utilized in the quarries with open excavation to reclaim the original land (Cerver.F.A, 1995). Requirement of high quantity of refill material makes this method uneconomical.
4) *Bench Planting:* In this method small quantity of soil is required to spread over the benches which consist of rock to create perfect climate for the development of vegetation (Land use consultants, 1992a). Normally small rooted plants are used due to constricted area present on the benches to help in cloaking the rock surface. While spreading the soil over the benches some part of the fill material falls into the fissures of rock which triggers the growth of vegetation and helps in the degradation of rock over the time.
5) *Restoration Blasting:* The aim of this method is to explode the quarry edge to replicate it as a natural one. Care should be taken while working with this method because it is a high potential technique used for the restoration compared to other process (Cripps et al, 2004) and requires alteration in the operations depending upon the land type (Yundt et al, 2002). Geographical, terrestrial, topographical and biotic parameters of land are considered before blasting. Restoration blasting forms soil slack which later helps in vegetation growth (Gunn.J and Bailey.D, 1993; Wheater.C.P andW.R.Cullen, 1997). This technique requires skilled employees, latest tools and equipments which make this method costlier compared to others.

V. PHYSICAL REMEDIATION

The soil replacement and thermal desorption are main physical remediation methods.

A. Soil Replacement Method

In soil replacement method polluted soil is exchanged with hygienic soil in turn to weaken the pollutant absorption and enhance the ecological capacity (Qian et al, 2000; Zhang et al, 2004). Soil substitution method is bifurcated into soil replacement, soil spading, new soil importing. a) Soil replacement method involves eliminating the polluted soil and exchanging it with fresh soil. This method suits for a small contaminated area. b) Soil spading focus on diluting and biologically degrading the pollutant by deep digging. c) New soil importing is inclusion of fresh soil into polluted area and wrapping the surface to dilute the pollutant concentration (Zhou et al, 2004).

B. Thermal Desorption

Thermal desorption is a reclamation technique which make use of heat to amplify the pollutants volatility. Steams, IR, microwave radiation are used to remove these volatile heavy metals from the solid matrix which are collected by vaccum negative pressure (Li et al., 2010). Thermal desorption is grouped as high temperature desorption (320-560ºC) and low temperature desorption (90-320ºC) (Aresta et al, 2008).

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue IX Sep 2021- Available at www.ijraset.com

Table 6: Types of Thermal Desorption.

TYPES	TEMPERATURE
High thermal desorption	320-560ºC
Low thermal desorption	90-320ºC

VI. CHEMICAL REMEDIATION

A. *Chemical Leaching*

Fresh water, gases, reagents and fluids are used to wash and eliminate pollutants from defile soil which is referred to as chemical leaching remediation method (Tampouris et al, 2001; Ou-Yang et al, 2010). The heavy metals in soil are converted from solid to liquid phase using adsorption, ions exchange, chelating and precipitation then recovered from the leachate.

Tokunage S and Hakuta T, 2002, investigated the variations in diverse concentration of HF, H_3PO_4, H_2SO_4, HCl, HNO_3 on extraction of As from synthetically contaminated soil using 2830mg/kg of As. It was observed that H_3PO_4 proved to be most favourable as an extractant, gaining 99.9% As extraction at 9.4% acid concentration in 6hr. H_2SO_4 also gained high % of extraction (Alam et al, 2001).

B. *Chemical Fixation*

Chemical fixation involves amalgamation of reagents to contaminated soil which forms insoluble matters that lower the voyage of heavy metals to ecosystem and thus attain soil remediation (Zhou et al, 2004).

In Cd defile soil remediation method, the results showed reduction in Cd components concentration up to 21.40, 27.24, 27.63 & 32.30% (Lv et al., 2009). As analyzed and observed the added sum was 20, 30, 40 & 50g/kg. Another study showed a reduction of 46% Cd concentration in soil when moderate attapulgite clay was used without compromising on crop yield and soil fertility (Fan et al, 2007).

Table 7: Reduction in Cd Concentration by Chemical Fixation.

Soil	Ratio in g/kg	Reduction in %
Cd	20	21.40
	30	27.24
	40	27.63
	50	32.30

C. *Electro-Kinetic Remediation*

Forming an electric gradient by mainly applying voltage on two sides of soil is called as Electro kinetic remediation technology. (Lou et al, 2004). To treat the pollutant further, it is carried to two poles treatment room via electro migration, electro osmotic flow or electrophoresis (Acar et al, 1993; Swartzbaugh et al, 1990). This method is cost effective and suitable for low permeable soil which does not alter the natural existence (Virkutyte et al, 2006). There are different approaches to remove heavy metal contaminated soil such as electrokinetic-oxidation or reduction (Cox et al, 1996), electrokinetic-microbe restoration (Yu et al, 2009).

D. *Vitrify Technology*

Vitrify approach is a method to heat the soil at 1400-2000ºC, where organic substance volatilize or degrade. The steam outcome and pyrolysis by-product was composed by off-gas treating process. The product after sometime takes rock vitreous shape and loses its mobility. The strength of vitreous is ten times the concrete. The energy can be transferred by combustion of fossil fuels or energizing electrode and later by plasma, arc & microwave energy in ex-situ restoration. Heat produced is passed to defile soil through the electrodes in in-situ restoration. Thus this method is efficient, but not cost effective and requires high energy (Fu JH, 2008).

VII. BIOLOGICAL REMEDIATION

A. Phytoremediation

Phytoremediation is a process in which vegetation is used as a media to remove pollutants from the contaminated sites. Plants act as filters or traps in degrading pollutants and stabilize metal contaminants (Shen ZG, Chen HM, 2000).

Few phytoremediation methods are listed below:

1) Phytoextraction, also called phytoaccumulation is a method in which metal contaminants are transferred from soil to different parts of the plant via roots. Based on the type of metals present in polluted site, one or more plants are selected for plantation. The plants are harvested after a certain period and composted or incinerated for metals recycling (Wang JL, Wen XH, 2001).

Table 8: Plant Species used in Phytoextraction

Phytotechnology	Phytoextraction
Pollutants	Trace metals (As, Co, Cu, Mn, Ni, Pb, Se, Zn, etc.
Properties of favourable plant	High levels of plant uptake, translocation and build up in harvestable tissues (hyperaccumulation occurs when concentration in up-ground tissues is in range 0.1-1% of the plant dry weight)
Plant species	Arachis pintoi; Zea mays; Brassica alba; Oryza sativa Hyperaccumulators: Phytolacca Americana (Mn); Alyssum bertolonii (Ni, Co); Noccaea caerulescens (Cd, Zn, Ni, Pb); Arabidopsis halleri (Cd, Zn); Sedum alfredii, Arabis paniculata (Zn)
Reference	Andreazza et al, 2011; Murakami and Ae, 2009; Kramer, 2010; Liu et al, 2010b; Tang et al, 2009; Deinlein et al, 2012

2) Phytostabilization is a methodology in which a specific group of plants are grown to absorb excess metal present in a contaminated site where natural vegetation is affected. This technique immobilizes the contaminants from transferring to the environment and thus entering the food chain (Wang HF, Zhao BW, Xu J, 2009).

Table 9: Plant Species used in Phytostabilization.

Phytotechnology	Phytostabilization
Pollutants	Organic and inorganic pollutants
Properties of favourable plant	High transpiration avoid leaching and surplus and entrenched grasses prevent the loss of crest soil and sediments
Plant species	Quercus robur; Pinus sylvestris; Pseudotsuga menziesii; Silene paradoxa; Aldama dentate
Reference	Nevel et al, 2011; Dasgupta-Schubert et al, 2011; Pignattelli et al, 2012

3) Phytodegradation is a practice where plants release their enzymes into the soil and breakdown the contaminants to use them as nutrients via plant tissues (EPA, 1999).

Table 10: Plant Species used in Phytodegradation.

Phytotechnology	Phytodegradation
Pollutants	Organics that are movable in plants (herbicides, TPHs, TNT, BTEX and RDX)
Properties of favourable plant	Huge, dense root systems and high levels of degrading enzymes
Plant species	Phalaris arundinacea; Lolium perenne; Abutilon avicennae; Phragmites australis
Reference	Panz and Miksch, 2012; Gerhardt et al, 2009

4) Rhizodegradation is the process in which micro-organisms such as bacteria, yeast, fungi, etc act upon contaminants present in the soil and digest organic substances for nutrients which in turn produce energy (EPA, 1999).

Table 11: Plant Species used in Rhizodegradation.

Phytotechnology	Rhizodegradation
Pollutants	Hydrophobic organic compounds (PCBs, PAHs and others)
Properties of favourable plant	Bulky root surface region favors the degradation method, as it promotes microbial growth and the production of particular exudates compounds
Plant species	Salix alaxensis; Picea glauca; Glycine max; Oryza sativa; Medicago sativa
Reference	Slater et al, 2011; Panz and Miksch, 2012; Gerhardt et al, 2009

5) In Phytovolatilization, the organic contaminants in soil and water are used by trees or plants to volatize metals with low concentration into the atmosphere (Watanabe ME, 1997; Bizily SP et al, 1999; Wang et al, 2001).

Table 12: Plant Species used in Phytovolatilization.

Phytotechnology	Phytovolatilization
Pollutants	Volatile organic compounds (TCE and MTBE) and few inorganics (Se and Hg)
Properties of favourable plant	High transpiration rate facilitates the mobility of these compounds throughout the plant
Plant species	Triticum aestivum; Brassica napus; Vigna sinensis; Saccharum officcinarum; Populus tremula x Populus alba
Reference	Dhillon et al, 2010 Gerhardt et al, 2009

B. Bio-Remediation

The restoration process involves rainfall, extracellular complextion, red- ox reaction, intracellular accumulation. Microbial straining is a common and innovative process for extracting metals from low grade ores and mineral quarries (Bosecker K, 2001). Lamber DH and Weidensaul T, 1991, investigated the impacts of sediments on mycorrhizal(MR) intake of P, Cu, Zn and confirm MR suppression of Cu and Zn intake by P. sediments decrease P intake at 150mg/kg P or larger in nonmycorrhizal(NMR) plants with small change in plant growth among sediments. Jayalath and Veena-Kumara-Adi recently published their article explaining the restoration of Physico-Chemical Properties of Zinc Contaminated Soil by Bacterial Biosurfactant.

C. Animal Remediation

Animal remediation is a process of description of few small insects adsorbing heavy metals, rottening and movement of the heavy metal, relocating and sinking the toxic levels. The study represents, treatment of earthworm-straw mulching combinations promotes plant Cu concentration, and the sum ascended by it was lesser than the earthworm treatment but greater than straw mulching treatment (Wang et al, 2007). Kou et al., 2008, reported the Pb absorption of earthworm through testing the Pb concentration in soils. The outcomes represented that earthworm could accumulate Pb efficiently. The accumulation is directly proportional to Pb concentration.

Table 13: Earthworm actions on heavy metal contaminated area

Earthworms	Plants	Soil nature	reference
Metaphire guillelmi	Ryegrass (*Lolium multiflorum*)	Cu pollution 400mg kg^{-1}	Dandan et al, 2007
Pheretima sp.	Ryegrass	Zn pollution at 400 mg kg^{-1}	Wang et al, 2006
Pheretima sp.	Indian mustard	Zn pollution at 400 mg kg^{-1}	Wang et al, 2006
Pheretima sp.	Ryegrass (*L.multiflorum)*	Cd pollution at 20 mg kg^{-1}	Yu et al,2005
Pheretima guillelmi	*Leucaena leucocephala*	Pb/Zn mine tailings at 1,202 mg Pb kg^{-1}	Ma et al, 2006
Pontoscolex corethrurus	*Lantana camara*	Pb pollution at 1,000 mg kg^{-1}	Jusselme et al, 2012, 2013

VIII. RE-VEGETATION AT ABANDONED MINE LAND

Vegetation plays an important role in protecting the soil from erosion due to wind and water and also allows the accumulation of fine particles (Tordoff et al, 2000; Conesa et al, 2007b). Their extensive root systems stabilize the soil by reverse degradation process. Once the vegetation is built, they improve the organic matter in the soil, maintain the soil pH, lower the bulk density of soil and fill the surface layer with minerals and nutrients. The plant collects and stores the mineral nutrient on the top surface of the soil in the organic form so that they are easily broken down by the microbes. (Li et al, 2006; Conesa et al, 2007a; Mendez et al, 2008a)

The selection of plants for the purpose of revegetation of eroded ecosystems is done based on the ability of plants to survive and regenerate under the severe conditions of both the nature of dump materials and their ability to stabilize the soil structure. (Madejon et al, 2006) Generally the plants selected for revegetation should be drought resistant, fast growing and also the one which can grow even in nutrient deficient soils. The main component that prevents vegetation is acidity; plants selected for revegetation must be tolerant to such sites consisting of metal contaminants. (Caravaca et al, 2002; Mendez and Maier, 2008b) The species which are already adapted for such conditions are preferred mostly indigenous species that are most likely to fit into the ecosystem and are easily adapted to the climate. If the exotic plants are introduced, they may become problematic weeds so they must be screened carefully before placing (Li et al, 2003; Chaney et al, 2007).

IX. CONCLUSION

In recent times, there is continuous development of technologies to remediate contaminated soil. Growing technologies aim on biological processes which mainly include vegetation, micro organisms and soil dependent insects for green, eco-friendly, combined, sedentary and fast remediation to cure polluted areas. The ill effects on the biosphere and on Homo sapiens can be reduced by using specific species of plants. The collection of heavy metals can be aided by vegetative plants and algae to reduce the effect of contaminants when compared to chemical methods. The main intention of the reclamation is to restore the ecological solidarity of the degraded areas.

The plants selected for the revegetation must be capable of surviving in the local environment and rebuilding the soil structure and to nurture the ecology. The regeneration and productiveness of the abandoned mine land will increase once there is revegetation, and the offsite damages also gets minimized. In addition to the ecological development revegetation also increases the aesthetic of the area. Reclamation must consider the function of the land as an integrated system which is above and below the ground so not only planting a new landscape can help in successful reclamation, it must go beyond revegetation.

X. ACKNOWLEDGMENTS

Authors wish to recognize the help from Principal, HOD, Civil department, PG coordinator, Environmental Engineering, the Administration Bapuji Institute of Engineering and Technology, Davanagere for facilitating the work carried out.

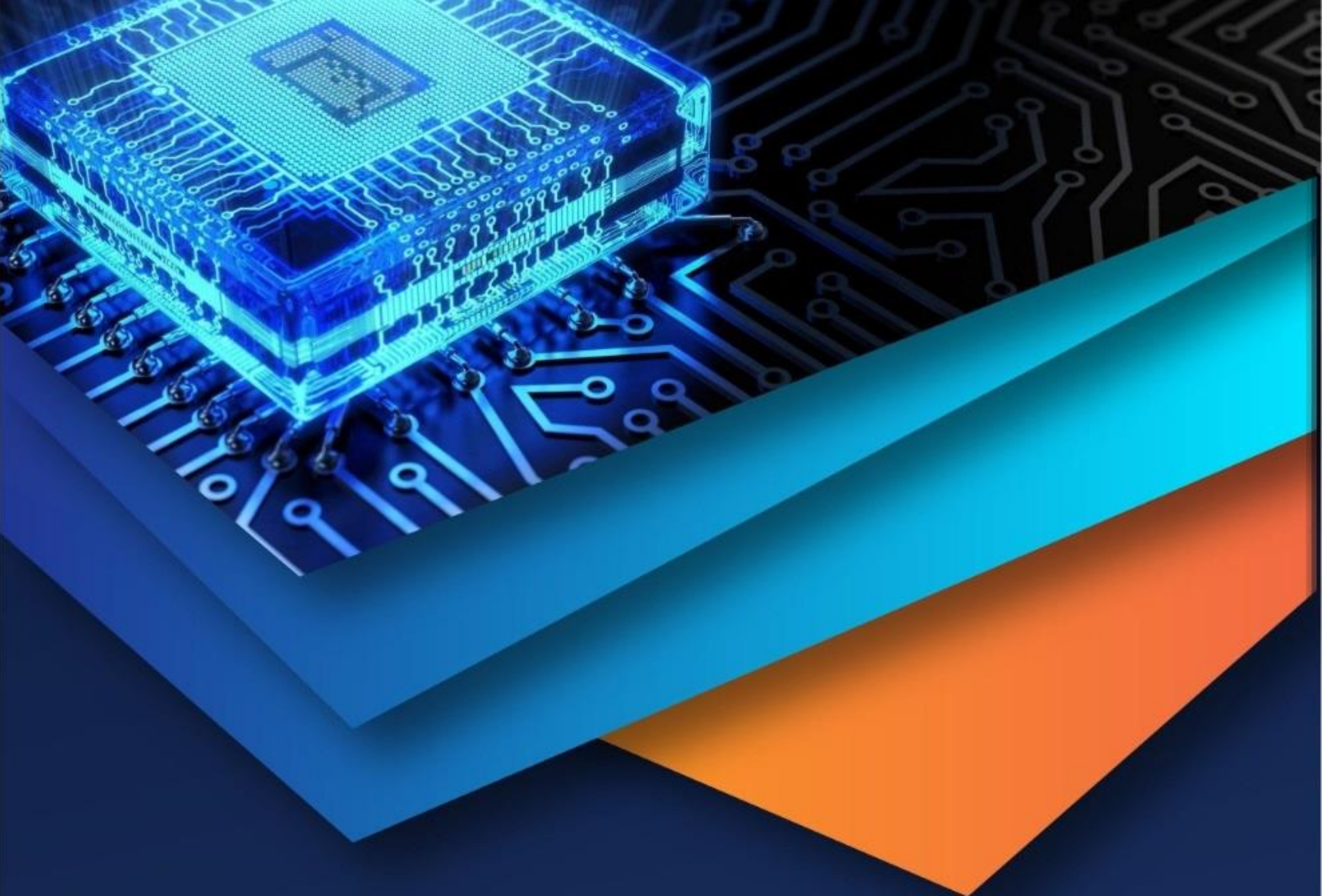
REFERENCES

[1] Acar YB, Alshawabkeh AN. Principles of electrokinetic remediation. Environmental Science & Technology, 1993; 27, 2638- 47.
[2] Addiscott, T.M., Whitmore, A.P., and Powlson, D.S. Farming fertilizers and the nitrate problem. CAB International, Wallingford, UK, 1991; 176 pp.
[3] Alam GM, Tokunaga S, Maekawa T. Extraction of arsenic in a synthetic arsenic contaminated soil using phosphate. Chemosphere, 2001; 43(8): 1035-41.
[4] Alshawabkeh AN, Bricka RM. Basics and application of electrokinetics remediation. In: Wise DL, Trantolo DJ, Cichon EJ, et al., eds. Remediation engineering of contaminated Soils. New York: Marcel Dekker Inc; 2000; p. 95-111.
[5] Andreazza, R., Bortolon, L., Pieniz, S., Giacometti, M., Roehrs, D. D., Lambais, M. R., and Camargo, F.A.O. Potential phytoextraction and Phytostabilization of perennial peanut on copper-contaminated vineyard soils and copper mining waste. Biol Trace Elem Res, 2011; 143: 1729–1739.
[6] Aresta M, Dibenedetto A, Fragale C, et al. Thermal desorption of polychlorobiphenyls from contaminated soils and their hydrodechlorination using Pd- and Rh-supported catalysts. Chemosphere, 2008; 70(6): 1052-8.
[7] Barcelo, J., and Poschenrieder, C. Phytoremediation: principles and perspectives. Contribution to Science, 2003; 2(3), 333-344
[8] Barkworth, H., and Bateson, M. An investigation into the bacteriology of top soil dumps. Plant Soil, 1964; 21(3), 345353.
[9] Bentham, H., Harris, J. A., Birch, P., and Short, K. C. Habitat classification and soil restoration assessment using analysis of soil microbiological and physico-chemical characteristics. The Journal of Applied Ecology, 1992; 29(3), 711718.
[10] Bosecker K. Microbial leaching in environmental clean-up programmes. Hydrometallurgy, 2001; 59(2-3): 245-8.
[11] Caravaca, F., Hernandez, M.T., Garcia, C., and Roldan, A. Improvement of rhizosphere aggregates stability of afforested semi- arid, plant species subjected to mycorrhizal inoculation and compost addition. Geoderma, 2002; 108, 133-144.
[12] Cerver, F. A. Civil Engineering; Nature conservation and land reclamation, Arco Editorial, Barcelona, 1995.
[13] Chaney, R.L., Angle, J.S., Broadhurst, C.L., Peters, C.A., Tappero, R.V., and Donald, L.S. Improved understanding of hyperaccumulation yields commercial phytoextraction and phytomining technologies. Journal Environmental Quality, 2007; 36, 1429-14423.
[14] Cilek, V. Reclamation and revitalization of limestone quarries - history and principles. Paper presented at the 11th ILA-Congress Prague, 2006.
[15] Conesa, H.M., Garcia, G., Faz, A., and Arnaldos, R. Dynamics of metal tolerant plant communities' development in mine tailings from the Cartagena-La Union Mining District (SE Spain) and their interest for further revegetation purposes. Chemosphere 68, 2007b; 1180-1185.
[16] Coppin, N.J., and Bradshaw, A.D. The establishment of vegetation in quarries and open-pit non-metal mines. Mining Journal Books, London, 1982; 112 p.
[17] Cox CD, Shoesmith MA, Ghosh MM. Electro kinetic remediation of mercury-contaminated soil using iodine/iodide lixiviant. Environmental Science & Technology, 1996; 30(6): 1933-38.
[18] Cripps, J.C., V. Roubos, D. Hughes, M. Burton, H. Crowther, A. Nolan, C. Travis, I.M. Nettleton, M.A. Czerewko, and D. Tonks. Reclamation planning in hard rock quarries: A guide to good practice. Mineral Industry Research Organisation (MIRO), 2004.
[19] Cullen W.R., C.P. Wheater, and P.J. Dunleavy. Establishment of species-rich vegetation on reclaimed limestone quarry faces in Derbyshire, UK. Biological Conservation, 1998; 84 (1):25-33. http://dx.doi.org/10.1016/S0006-3207(97)00089-X
[20] D.C.Adriano, Trace Elements in Terrestrial Environments: Biogeochemistry, Bioavailability and Risks of Metals, Springer, New York, NY,USA, 2nd edition, 2003.
[21] Dandan.W et al role of earthworm – straw interactions on phytoremediation of Cu contaminated soil by ryegrass. Acta Ecol Sinica, 2007; 27: 1292-1298.
[22] Daniels, W. L. Creation and Management of Productive Mine Soils, Powell River Project Reclamation Guide lines for Surface-Mined Land in Southwest Virginia, 1999. http://www.ext.vt.edu/pubs/mines/460-121/460-121.html.
[23] Das, M., and Maiti, S.K. Metal mine waste and phytoremediation. Asian Journal of Water, Environment and Pollution, 2005; 4(1), 169-176.
[24] Dasgupta-Schubert, N., Barrera, M. G., Alvarado, C. J., Castillo, O. S., Zaragoza, E. M., Alexander, S., Landsberger, S., and Robinson, S. The uptake of copper by aldama dentata: Ecophysiological response, its modeling, and the implication for phytoremediation. Water Air Soil Poll, 2011; 220: 37–55.
[25] Davies, R., and Hodgkinson, R., Younger, A. and Chapman, R. Nitrogen loss from a soil restored after surface mining. Journal Environmental Quality, 1995; 24, 1215-1222.
[26] Davies, R., and Younger, A. The effect of different post- restoration cropping regimes on some physical properties of a restored soil. Soil Use and Management, 1994; 10, 55-60.
[27] Davis, B.N.K., K.H. Lakhani, M.C. Brown, and D.G. Park. Early Seral communities in a limestone quarry: An experimental study of treatment effects on cover and richness of vegetation. Journal of Applied Ecology, 1985; 22:473-490. http://dx.doi.org/10.2307/2403179.
[28] Deinlein, U., Weber, M., Schmidt, H., Rensch, S., Trampczynska, A., Hansen, T. H., Husted, S., Schjoerring, J. K., Talke, I. N., Kramer, U., and Clemens, S. Elevated nicotianamine levels in Arabidopsis halleri roots play a key role in zinc hyperaccumulation. Plant Cell, 2012; 24: 708–723.
[29] Dexter, A.R. Advances in the characterization of soil structure. Soil and Tillage Research, 1988; 11, 199-238.
[30] Dhillon, K. S., Dhillon, S. K., and Dogra, R. Selenium accumulation by forage and grain crops and volatilization from seleniferous soils amended with different organic materials. Chemosphere, 2010; 78: 548–556.

[31] Donahue, R.L., Miller, R.W., and Shickluna, J.C. Soils: An introduction to soils and plant growth (5th ed.). Prentice-Hall, 1990; 234 p.
[32] Edgerton, D.L., Harris, J. A., Birch, P., and Bullock, P. Linear relationship between aggregate stability and microbial biomass in three restored soils. Soil Biology and Biochemistry, 1995; 27, 1499-1501.
[33] Elkins, N.Z., Parker, L.W., Aldon, E., and Whitford, W.G. Responses of soil biota to organic amendments in stripmine spoil in northwestern New Mexico. Journal Environmental Quality, 1984; 13, 215-219
[34] EPA 542-B-99-003 June 1999; www.epa.gov/tioclu-in.org
[35] Fan DF, Huang SS, Liao QL, et al. Restoring experiment on Cadmium polluted vegetable lands with attapulgite of varied dose. Jiangsu Geology, 2007; 31(4): 323-8.
[36] Faramarz Jalali, "Enhanced Bioremediation of a Soil Contaminated with both Petroleum Hydrocarbon and Heavy Metals with in Soil Biosurfactant Production", A Thesis in the Department of Building, Civil, and Environmental Engineering, Concordia University Montreal, Quebec, Canada, 2007.
[37] Fu JH. The research status of soil remediation in China. Annual meeting of Chinese society for environmental sciences, 2008; 1056-60.
[38] Gerhardt, K. E., Huang, X.-D., Glick, B. R., and Greenberg, B. M. Phytoremediation and rhizoremediation of organic soil contaminants: Potential and challenges. Plant Science, 2009; 176: 20–30.
[39] Ghose, M.K. Land reclamation and protection of environment from the effect of coal mining operation. Mine technology, 1989; 10(5), 35-39.
[40] Ghose, M.K. Soil conservation for rehabilitation and revegetation of mine-degraded land. TIDEE – TERI Information Digest on Energy and Environment, 2005; 4(2), 137-150.
[41] Ghosh, A.B., Bajaj, J.C., Hassan, R., and Singh, D. Soil and water testing methods- A laboratory manual, IARI, New Delhi, 1983;31-36.
[42] Gil-Sotres, F., Trasr-Cepeda, C., Leiros, M.C., and Seoane, S. Different approaches to evaluating soil quality using biochemical properties. Soil Biology and Biochemistry, 2005; 37, 877-887.
[43] Gitt, M. J., and Dollhopf, D. J. Coal waste reclamation using automated weathering to predict lime requirement. Journal Environmental Quality, 1991; 20, 285-288.
[44] Glick, B.R., Patten, C.L., Holguin, G., and Penrose, D.M. Biochemical and genetic mechanisms used by plant growth-promoting bacteria. Imperial College Press, London, UK, 1999; 280p.
[45] Gould, A.B., Hendrix, J. W., and Ferriss, R. S. Relationship of mycorrhizal activity to time following reclamation of surface mine land in western Kentucky. I Propagule and spore population densities. Canadian Journal Botany, 1996; 74, 247-261.
[46] Gregorich, E.G., Kachanoski, R.G., and Voroney, R.P. Carbon mineralization in soil size fractions after various amounts of aggregate disruption. Journal of Soil Science, 1989; 40,649-659.
[47] Gunn, J. and Bailey, D. Limestone quarrying and quarry reclamation in Britain. Environmental Geology, 1993; 21:167-172. http://dx.doi.org/10.1007/BF00775301.
[48] Hands, D.E. and R.D. Brown. Enhancing visual preference of ecological rehabilitation sites. Landscape and Urban Planning, 2002; 58 (1):57-70. http://dx.doi.org/10.1016/S0169-2046(01)00240-7.
[49] Harris, J.P., Birch, P., and Short, K.C. Changes in the microbial community and physio-chemical characteristics of top soils stockpiled during opencast mining. Soil Use Management, 1989; 5, 161-168.
[50] Haywood, S.M. Mineral landscapes: The next ten years? Environmental Geochemistry and Health, 1979; 1(1):25-30. http://dx.doi.org/10.1007/bf02010594.
[51] Hendrychová, M. Reclamation success in post-mining landscapes in the Czech Republic: A review of pedagogical and biological studies. Journal of Landscape Studies,2008; 1:63-78.
[52] Heras, M.M.L. Development of soil physical structure and biological functionality in mining spoils affected by soil erosion in a Mediterranean-Continental environment. Geoderma, 2009; 149, 249-256. http://dx.doi.org/10.1046/j.1526-100X.1997.09708.x.
[53] Hu, Z., Caudle, R.D., and Chong, S.K. Evaluation of firm land reclamation effectiveness based on reclaimed mine properties. International Journal of Surface Mining Reclamation and Environment, 1992; 6,129- 135.
[54] Hunter, F., and Currie, J.A. Structural changes during bulk soil storage. Journal of Soil Science, 1956; 7, 75-86.
[55] Indian Bureau of Mines, 2003.
[56] Isermann, K. Agriculture's share in emission of trace gases affecting the climate and some cause oriented proposals for sufficiently reducing this share. Environmental Pollution, 1994; 83,95-111.
[57] Jayalatha N. A and Veena Kumara Adi "Restoration of Physico-Chemical Properties of Zinc Contaminated Soil by Bacterial Biosurfactant" in International Journal of Current Trends in Science and Technology, (2017). ISSN 0976-9730 Vol. 7, no. 10, pp. 20329-20335. https://doi.org/10.15520/ctst.v7i10.59
[58] Jha, A.K., and Singh, J.S. Growth performance of certain directly seeded plants on mine spoil in a dry tropical environment, India Forest, 1993; 119,920-927.
[59] Johnson, D.B., and Williamson, J.C. Conservation of mineral nitrogen in restored soils at opencast mines sites: I. Result from field studies of nitrogen transformations following restoration. European Journal of Soil Science, 1994; 45, 311-317.
[60] Johnson, D.B., Williamson, J.C., and Bailey, A.J. Microbiology of soils at opencast sites. I. Short and Long- term transformation in stockpiled soils. Journal of Soil Science, 1991; 42, 1-8.
[61] Jusselme MD et al, effect of earthworms on plant lantana camara Pb-uptake and on bacterial communities in root- adhering soil. Sci Total Environ, 2012; 416:200-207.
[62] Jusselme MD et al, increased lead availability and enzyme activities in root-adhering soil of lantana camara during Phytoextraction in the presence of earthworms. Sci Total Environ , 2013; 445-446:101-109.
[63] Kay, B.D. Rate of change of soil structure under different cropping systems. In: Advances in soil structure. Vol. 12, Springer- Verlag. New York, 1990; 1-52.
[64] Kenny, D.R., and Bremner, J.M. Chemical index of soil nitrogen availability. Nature, 1966; 211, 892- 893.
[65] Khan, A.G., Role of soil microbes in the rhizospheres of plants growing on trace lement contaminated soils in phytoremediation. J. Trace Elem. Med. Biol., 2005; 18(4), 355-364.
[66] Kou YG, Fu XY, Hou PQ, et al. The study of lead accumulation of earthworm in lead pollution soil. Environmental Science and Management, 2008; 33(1): 62-4, 73.
[67] Kramer, U. Metal hyperaccumulation in plants. Annu Rev Plant Biol, 2010; 61: 517–534.

[68] Kundu, N.K., and Ghose, M.K. Soil profile Characteristic in Rajmahal Coalfield area. Indian Journal of Soil and Water Conservation, 1997; 25 (1), 28-32.
[69] Kundu, N.K., and Ghose, M.K. Status of soil quality in subsided areas caused by underground coal mining. Indian Journal of Soil and Water Conservation, 1998a; 25 (2), 110-113.
[70] Kundu, N.K., and Ghose, M.K. Studies on the existing plant communities in Eastern coalfield areas with a view to reclamation of mined out lands. Journal of Environmental Biology, 1998b; 19 (1), 83-89.
[71] Lamber DH, Weidensaul T. Element uptake by mycorrhizal soyean from sewage-treated soil. Soil Sci. Soc. Am. J. 1991; 55(2): 393-8.
[72] Land Use Consultants, Amenity reclamation of mineral working; main report. Crown, London, 1992a.
[73] Li J, Zhang GN, Li Y. Review on the remediation technologies of POPs. Hebei Environmental Science, 2010; 65-8.
[74] Li, M.S. Ecological restoration of mineland with particular reference to the metalliferous mine wasteland in China:a review of research and practice. Soil Total Environment, 2006; 357, 38-53
[75] Li, Y.M., Chaney, R.L., Brewer, E.P., Roseberg, R.J., Angle, J.S., Baker, A.J.M., Reeves, R.D., and Nelkin, J. Development of a technology for commercial phytoextraction of nickel: Economic and technical considerations. Plant Soil, 2003; 249, 107-115.
[76] Lindemann, W. C., Lindsey, D. L., and Fresquez, P. R. Amendment of mine spoils to increase the number and activity of microorganisms. Soil Sci. Soc. Am. Journal, 1984; 48,574-578.
[77] Lindsay, W.L., and Norvell, W.A. Development of DTPA tests for Fe, Mn, Cu, and Zn. Soil Science Society American Journal, 1978; 42, 421- 428.
[78] Liu, P., Tang, X.M., Gong, C. F., and Xu, G. D. Manganese tolerance
[79] Luo QS, Zhang XH, Wang H, et al. Mobilization of 2,4-dichlorophenol in soils by non-uniform electrokinetics. Acta Scientiae Circumstantiae, 2004; 24(6): 1104-9.
[80] Luo QS, Zhang XH, Wang H. Influence of non-uniform electrokinetic remediation technology on soil properties. Chinese Journal of Environmental Engineering, 2004; 5(4): 40-5.
[81] Lv LL, Jin MY, Li BW, et al. Study on remediation of the soil contaminated with cadmium by applying four minerals. Journal of Agriculture University of Hebei, 2009; 32(1): 1-5.
[82] Ma Y, Dickinson N, Wong M, beneficial effects of earthworms and arbuscular mycorrhizal fungi on establishment of leguminous trees on Pb/Zn mine tailings. Soil Biol Biochem, 2006; 38:1403-1412
[83] Madejon, E., de Mora, A.P., Felipe, E., Burgos, P., and Cabrera, F. Soil amendments reduce trace element solubility in a contaminated soil and allow regrowth of natural vegetation. Environment Pollution, 2006; 139, 40-52.
[84] Maiti, S.K. and Ghose, M.K. Ecological restoration of acidic coal mine overburden dumps- an Indian case study. Land Contamination and Reclamation, 2005; 13(4), 361-369.
[85] Maiti, S.K., and Saxena, N.C. Biological reclamation of coal mine spoils without topsoil: an amendment study with domestic raw sewage and grass-legumes mixture. International Journal of Surface mining, Reclamation and Environment, 1998; 12, 87-90
[86] Maiti, S.K., Karmakar, N.C., and Sinha, I.N. Studies into some physical parameters aiding biological reclamation of mine spoil dump- a case study from Jharia coal field. Indian Mining Engineering Journal, 2002; 41, 20-23.
[87] Mendez, M. O., and Maier, R.M. Phytoremediation of mine tailings in temperate and arid environments. Reviews Environmental Science and Biotechnology, 2008a; 7, 47-59.
[88] Mendez, M.O., and Maier, R.M. Phytostabilization of mine tailings in arid and semiarid environments-An emerging remediation technology. Environmental Health Perspectives, 2008b; 116 (3), 278-283.
[89] Miller, R.M., Carnes, B. A., and Moorman, T. B. Factors influencing survival of vesicular-arbuscular mycorrhiza propagules during topsoil storage. Journal Applied Ecology, 1985; 22,259-266.
[90] Moffat, A. and J. McNeill, Reclaiming disturbed land for forestry, Bulletin 110. HMSO, London, 1994.
[91] Moreno-de las Heras, M., Nicolau, J.M., and Espigares. M.T. Vegetation succession in reclaimed coal mining sloped in a Mediterranean-dry environment. Ecological Engineering, 2008; 34, 168-178.
[92] Murakami, M. and Ae, N. Potential for phytoextraction of copper, lead, and zinc by rice (Oryza sativa L.), soybean (Glycine max [L.] Merr.), and maize (Zea mays L.). J Hazard Mater, 2009; 162: 1185–1192.
[93] Nicolau, J.M, Trends in relief design and construction in opencast mining reclamation. Lands Degradation and Development, 2003;14:215-226. http://dx.doi.org/10.1002/ldr.548.
[94] Nicolau, J.M. Runoff generation and routing in a Mediterranean-continental environment:the Teruel coalfield, Spain. Hydrological Processes, 2002; 16, 631-647.
[95] Novak, J. and M. Konvicka, Proximity of valuable habitats affects succession patterns in abandoned quarries. Ecological Engineering, 2006; 26 (2): 113-122. http://dx.doi.org/10.1016/j.ecoleng.2005.06.008.
[96] Ou-Yang X, Chen JW, Zhang XG. Advance in supercritical CO2 fluid extraction of contaminants from soil. Geological Bulletin of China, 2010; 29(11): 1655-61.
[97] Page MM, Page CL. Elcetroremediation of contaminated soils. J. Environ. Eng. 2002; 128(3): 208-19.
[98] Panz, K. and Miksch, K. Phytoremediation of explosives (TNT, RDX, HMX) by wild-type and transgenic plants. J Environ Manage, 2012; 113: 85–92.
[99] Pignattelli, S., Colzi, I., Buccianti, A., Cecchi, L., Arnetoli, M., Monnanni, R., Gabbrielli, R., and Gonnelli, C. Exploring element accumulation patterns of a metal excluder plant naturally colonizing a highly contaminated soil. J Hazard Mater, 2012; 227: 362–369.
[100] Qian SQ, Liu Z. An overview of development in the soil-remediation technologies. Chemical Industrial and Engineering Process, 2000; 4: 10-2, 20.
[101] Rimmer, L.D., and Younger, A. Land reclamation after coal- mining operations. In: Hester, R.E., Harrison, R.M. (Eds), Contaminated Land and its Reclamation. Thomas Telford, London, 1997; pp.73-90.
[102] Rives, C. S., Bajwa, M. I., and Liberta, A. E. Effects of topsoil storage during surface mining on the viability of VA mycorrhiza. Soil Science, 1980; 129, 253-257.
[103] Schmidt, U. Enhancing phytoextraction: The Effect of chemical soil manipulation on mobility, plant accumulation, and leaching of heavy metals. Journal Environmental Quality, 2003; 32, 1939-1954. Sendlein

[104]Shen ZG, Chen HM. Bioremediation of heavy metal polluted soils. Rural Eco-Environment, 2000; 16(2): 39-44.
[105]Sheoran, A.S., and Sheoran, V. Heavy metal removal mechanism of acid mine drainage in wetlands: A critical review. Minerals Engineering, 2006; 19 (2), 105-116.
[106]Sheoran, A.S., Sheoran, V., and Poonia, P. Rehabilitation of mine degraded land by metallophytes. Mining Engineers Journal, 2008; 10 (3), 11-16.
[107]Sheoran, V., Sheoran, A.S., and Poonia, P. Phytomining: A review. Minerals Engineering, 2009; 22(12), 1007–1019.
[108]Singh, A.N., and Singh, A. N. Experiments on ecological restoration of coal mine spoil using native trees in a dry tropical environment, India: a synthesis. New Forests, 2006; 31.25-39.
[109]Singh, A.N., and Singh, J.S. Biomass and net primary production and impact of bamboo plantation on soil redevelopment in a dry tropical region. For. Ecol. Manag, 1999; 119, 195- 207.
[110]Singh, A.N., Raghubanahi, A.S., and Singh, J.S. Impact of native tree plantations on mine spoil in a dry tropical environment. Forest Ecol. Management, 2004; 187, 49-60
[111]Six, J., Bossuyt, H., Degryze, S., and Denef, K. A history of research on the link between aggregates, soil biota, and soil organic matter dynamics. Soil and Tillage Research, 2004;79, 7-31.
[112]Slater, H., Gouin, T., and Leigh, M. B. Assessing the potential for rhizoremediation of PCB contaminated soils in northern regions using native tree species. Chemosphere, 2011; 84: 199–206.
[113]Swartzbaugh JT, Weisman A, Gabrera-Guzman D. The use of electrokinetics for hazardous waste site remediation. Journal of Air and Waste Management Association. 1990; 40(12): 1670-7.
[114]T.A.Kirpichtchikova, A. Manceau, L.Spadini, F.Panfili, M.A.Marcus and T.Jacquet, "Speciation and solubility of heavy metals in contaminated soil using X-ray microfluorescence, EXAFS spectroscopy, chemical extraction and thermodynamic modelling," *Geochimica et Cosmochimica Acta*, 2006; vol.70, no.9, pp. 2163-2190.
[115]Tampouris S, Papassiopi N, Paspaliaris I. Removal of contaminant metals from fine grained soils, using agglomeration chloride solutions and pile leaching techniques. Journal of Hazardous Materials, 2001; 84(2-3): 297-319.
[116]Tang, Y. T., Qiu, R.L., Zeng, X.W., Ying, R. R., Yu, F. M., and Zhou, X. Y. Lead, zinc, cadmium hyperaccumulation and growth stimulation in Arabis paniculata Franch. Environ Exp Bot, 2009; 66: 126–134.
[117]Tokunaga S, Hakuta T. Acid washing and stabilization of an artificial arsenic-contaminated soil. Chemosphere, 2002; 46(1): 31-8.
[118]Tordoff, G.M., Baker, A.J.M., and Willis, A.J. Current approaches to the revegetation and reclamation of metalliferous mine wastes. Chemosphere, 2000; 41, 219–228.
[119]Van Nevel, L., Mertens, J., Staelens, J., De Schrijver, A., Tack, F. M. G., De Neve, S., Meers, E., and Verheyen, K. Elevated Cd and Zn uptake by aspen limits the phytostabilization potential compared to five other tree species. Ecol Eng, 2011; 37: 1072–1080.
[120]Virkutyte J, Sillanpaa M, Latostemaa P. Electrokinetic soil remediation-critical overview. The Science of the Total Environment, 2002; 289(113): 97-121.
[121]Visser, S., Fujikawa, J., Griffiths, C.L., and Parkinson, D. Effect of topsoil storage on microbial activity, primary production and decomposition potential. Plant and Soil, 1984; 82, 41-50.
[122]Walton, G., D. Jarvis, D. Jameson, J. Meadowcroft, M. Brown, and A. Carter. Secure and sustainable final slope for SME aggregate quarries. John Carpenter, Envenlode Books, Oxford, 2004.
[123]Wang D et al, Effect of earthworm on the phytoremediation of Zinc – polluted soil by ryegrass and Indian mustard. Biol fertile soils, 2006; 43:120-123.
[124]Wang DD, Li HX, Hu F, et al. Role of earthworm-straw interactions on phytoremediation of Cu contaminated soil by ryegrass. Acta Ecologica Sinica, 2007; 27(4): 1292-98.
[125]Wang HF, Zhao BW, Xu J, et al. Technology and research progress on remediation of soils contaminated by heavy metals. Environmental Science and Management, 2009; 34(11): 15-20.
[126]Wang JL, Wen XH. Environmental Biotechnology. Beijing: Tsinghua University press; 2001.
[127]Water Front Trail, Pit and quarry restoration; site characteristics. http://www.waterfronttrail.org/pdfs/books/restoring/section%207.pdf. Accessed 26/02/2010.
[128]Wheater C.P and W.R. Cullen, The flora and invertebrate fauna of abandoned limestone quarries in Derbyshire, United Kingdom. Restoration Ecology, 1997; 5 (1):77-84.
[129]Williamson, J.C., and Johnson, D.B. Microbiology of soils at opencast sites: II. Population transformations occurring following land restoration and the influence of rye grass/ fertilizer amendments. Journal Soil Science, 1991; 42, 9-16.
[130]Wong, M.H. Ecological restoration of mine degraded soils, with emphasis on metal contaminated soils. Chemosphere, 2003; 50,775–780.
[131]Xu Q, Huang XF, Cheng JJ, et al. Progress on electrokinetic remediation and its combined methods for POPs from contaminated soils. Environmental Science, 2006; 27(11): 2363-8.
[132]Yu X, Cheng J, Wong M, earthworm-mycorrhiza interation on Cd uptake and growth of Ryegrass. Soil Biol Biochem, 2005; 37:195-201.
[133]Yu YT, Tian GM, He MM. Comparison of two different combined bioleaching-electrokinetic remediation processes. Acta Scientiae Circumstantiae, 2009; 29(1): 163-8.
[134]Yundt, S.E., S. Miq, and B. Lowe, Quarry reclamation- cliffs, landforms and ecology. In: 26th Annual British Columbia Reclamation Symposium, Dawson Creek, British Columbia, 2002.
[135]Zhang XH, Wang H, Luo QS. Electrokinetics in remediation of contaminated groundwater and soils. Advances In Water Science, 2001; 12(2): 249-55.
[136]Zhang YF, Sheng JC, Lu QY. Review on the soil remediation technologies. Gansu Agricultural Science and Technology, 2004; 10: 36-8.
[137]Zhou DM, Hao XZ, Xue Y, et al. Advances in remediation technologies of contaminated soils. Ecology and Environmental Sciences, 2004; 13(2): 234-42.



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