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Top Soil Management in Coal Mines: A Paradigm Shift Required in Approach

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Abstract* : Top soil preservation & management is an important conditions while grant of Environmental Clearance and Consent to operate in coal mines . However, it is often observed that due to lack of understanding its importance, the level of commitment in its preservation is lacking. The problem is compounded with land availability constraint and lack of available specialized agencies for doing this work. Like Water (prevention & Control of Pollution Act) 1974 and Air (prevention & Control of Pollution Act) 1981, there is no separate act for Soil Management and there are no stringent criteria for its regular monitoring and reporting mandated by regulatory agencies. In light of the above, there is need to give it due importance that it deserves and like disposal of hazardous waste at designated sites, the top soil should also be managed by specialized agencies and if need be transported to far off places also. Initially the cost may seem prohibitive but the benefits of its preservation cannot be lost sight of. This paper highlights the importance of top soil management, the various practices in vogue and suggests measures that may be taken to improve the top soil preservation.
Key Words : Top Soil, Soil erosion, stockpiling, overburden, reclamation, sub soil.

Introduction : Soil is one of the most important natural resources on the earth. Most of the life forms on earth depend on soil as it is a direct or indirect source of food for them. Plants obtain their nutrients from the soil and animals are dependent on them. Soil is home to many different forms of life. Soil has been formed by weathering, erosion and decay of living plant and animal matter, however, valuable top soil is formed so slowly that it should be protected and valued because it can not be replaced in a life time of a man. Soil can be defined as the naturally occurring, loosed covering of broken rock particles and decaying organic matter (humus) on the surface of the earth which is capable of supporting life.

Process of Soil formation: Soil formation is the combined effect of physical, chemical and biological processes on soil parent material, the rocks. This process is termed as weathering, physical weathering and chemical weathering. Agents of physical weathering are : temperature, water, wind, plants & animals etc. Chemical weathering takes place due to following factors : Organic acids released during the decomposition of organic matter & the solvent action of water that dissolves the soluble salts forming solutions that further hasten the process of weathering.

Soil Profile: The soil consists of various layers called soil horizons and the arrangement of these horizons in soil a soil is known as a soil profile. Each soil horizon is different from the other in texture, colour, chemical composition and depth.

(i) ***O Horizon**: It is the top organic layer of soil, made up mostly of leaf litter and humus (decomposed organic matter).*
(ii) ***A Horizon:** This layer is also called top soil. It is found below the O horizon. Seeds germinate and plants grow in this dark colored layer. It is made up of humus (decomposed organic matter) mixed with mineral particles. Sometimes in the lower part of A-horizon, leaching of minerals and clay content takes place as water drips through this region. The process of leaching is called eluviations.*
(iii) ***B Horizon:** It is also called the sub soil-this layer is beneath the A Horizon and above the C Horizon. It contains clay and minerals deposits like iron, aluminum oxides and calcium carbonates that it receives from layers above it when mineralized water drips from the soil above.*
(iv) ***C Horizon:** The layer beneath the B horizon and above the R horizon. It consists of slightly broken up bed rock. Plants roots do not penetrate this layer, very little organic materials is found in this layer.*
(v) ***R Horizon:** This consists of the un weathered rock layer that is beneath all the other layers.*

Soil as a Resource: Soil material is critical component in the mining industry, where massive volume of soil is involved particularly in open cast mining. Soil resources are critical to the environment, as well as to food and fiber production. Soil provides minerals and water to plants. Soil absorbs rainwater and releases it later thus preventing floods and drought. Soil cleans the water as it percolates and is the habitat of many organisms.
Environmental Clearance Conditions mandated by Ministry of Environment & Forest in respect of top Soil management: Top soil should be stacked properly with proper slopes at earmarked site(S) with adequate measure and should be used for reclamation and rehabilitation of reclaimed areas.

Consent to operate conditions as per State Pollution Control Boards: The top soil and external overburden shall be removed separately and stored in a separate heap, duly covered with grass and vegetation or utilized for reclamation of mined out area. Internal overburden shall be utilized for backfilling of mined out area. The backfilled area shall be biologically reclaimed. Check dams shall be constructed at strategic points in order to guide all surface run off water containing sediments for settlement of suspended solids before discharge on land or any surface water body during monsoon after meeting the standards prescribed in consent order.

Soil Pollution: Soil pollution is defined as the buildup in soils of persistent toxic compounds, chemicals, salts, radioactive materials, or disease causing agents, which have adverse effect on plant growth and animal health. Soil pollution is caused by factors like use of chemical pesticides, excessive use of fertilizers, percolation of contaminated surface water to subsurface strata, oil and fuel dumping, leaching of wastes from landfills or direct discharge of industrial wastes in to the soil.

The effects on topsoil of long-term storage in stockpiles:

In open cast mines, coal evacuation is done by open excavation of the land and approaching the coal strata by excavating the entire earth mass lying above the coal starta. During mine quarrying, topsoil is first stripped from the site and stored in large heaps. These remain *in situ* for many years before the soil is reused and it is generally believed that there is a great reduction in the 'quality' of the soil during that period.

A study of stockpiles of different size, age and soil type has revealed that biological, chemical and physical changes do occur, mainly as a result of anaerobic conditions within the heaps, but also as a result of mechanized handling during the stripping and stockpiling. Visible changes occur within 0.3 m of the surface of stockpiles of clayey textured soils, but only below about 2 m depth for sandy textures. These visible changes are accompanied by chemical changes, particularly in the forms of nitrogen present but also in the content of available nutrients, pH and organic matter levels. Biological changes include reductions in potential for mycorrhizal infection, soil biomass and especially earthworm population. The soil atmosphere contains high levels of carbon dioxide, methane, ethane and ethylene. Physical changes include reduction in aggregate stability and resistance to compaction, increase in bulk density and changes in pore size distribution and micro-structure, as revealed by scanning electron microscopy.

Soil takes centuries to develop from parent material and organic matter. In a study of soil development of six sites where surface mines existed between 5 and 64 years earlier, the depth of the newly developed soil horizon in the 5-year-old site was 3 cm compared to 35 cm in the 55-year-old site (Thomas & Jansen 1985). Stockpiling and the subsequent reapplication of the topsoil, allows for planting conditions that are closer to the pre-disturbance condition than planting on the subsoil layers that remain. If stockpiled soil is reapplied quickly, with care to reduce the compaction inherent in the use of mechanical means for stockpiling, production potential remains. Limited evidence suggests that many of the adverse effects quickly disappear when the soil is respired.

Soil Removal and Storage Practices:-In the case of mining operations, the Stockpiling process involves removal of the topsoil layer and other soil layers necessary to get to the coal that is to be mined. The topsoil is removed first and stockpiled in one pile and the soil layer below is also removed and stockpiled separately. This subsoil layer is referred to as the overburden. Stockpiles are often meters deep. When mining operations are complete, the overburden material is reapplied and leveled and then the topsoil is reapplied and spread over the overburden material to provide a planting medium Both removal and replacement of the soil layers involves the use of heavy equipment. Because mining operations involve removal and storage of both layers, mixing of subsoil and topsoil layers can create plant establishment problems. The subsoil layers lack the organic and microbial organisms necessary to sustain plants. Mining operations often require that topsoil be stored in stockpiles for long periods of time, often several years.

The layer just below the topsoil contains very little organic material and by comparison to topsoil is poorly aggregated. It is therefore stockpiled separately. Replacement and removal usually involves the use of heavy equipment. The existing guidelines for replacement of topsoil in Environment Clearance conditions of mining projects do not specify the replacement thickness of topsoil. It is left to the wisdom of Coal Companies to identify the depth of top soil and preserve the same. The primary goal of Coal Company is to produce the coal at the minimum cost. The idea of replacement of topsoil to create a planting medium is a secondary consideration for coal companies and often compliance is done not on technical consideration as per site conditions but only to meet the compliance conditions.

Changes in Soils during Storage: The natural process of soil development can take hundreds of years. Stockpiled topsoil becomes highly degraded the moment this long-term structure is disturbed. The timeframe where the most damage occurs is when topsoil is initially stripped from the ground. Changes that occur in soil include increased bulk density, decreased water holding capacity, chemical changes, reduced nutrient cycling, reduced microbial activity, and loss or reduction of viable plant remnants and seeds.

Abdul-Kareem and Mc Rae (1984) state that while it is clear that adverse effects due to storage and earthmoving equipment exist, the extent of deterioration of soil in stockpiles has been greatly overestimated. They go on to say that their studies in England show that there is no reason why soils should not continue to be stockpiled although with greater care given to minimize compaction and mixing of topsoil with subsoil. Studies by Williamson and others (1990 as well as Widowson and others (1982), conducted in Wales and New Zealand, have shown that the soil pH, and the mineral content of stockpiled soils are not effected, as long as the soil is not stored for long periods of time in deep stockpiles. These studies have also found that the soil biology of stockpiled topsoil bounces back relatively quickly once the soil is re-spread. However, Harris and Birch (1989) noted that when soil was stockpiled in piles that were more than a meter deep, chemical effects such as accumulation of ammonium and anaerobic conditions occurred in the topsoil at the base of the pile. Other detrimental biological effects include absence of propagules and decrease in viability of buried seeds. In their study of soil microbial activity in British opencast coal mine restorations that utilized stockpiling techniques, Harris and Birch (1989) found less carbon stored in the soil and that this decreased further after re-spreading. Their study also noted detrimental effects of topsoil storage including heavy losses in the microbial community and decreased nutrient cycling. In studies conducted by Visser and others (1984) in Alberta, Canada, one of the most immediate consequences of stockpiling they noted was the loss of organic carbon levels. Organic carbon levels were reduced by as much as thirty percent. This reduction in carbon was an immediate rather than a slow loss over the duration of the study. This assertion is further backed up by research conducted by Jordon (1998) who found major losses of nutrients from ecosystems to generally occur when the nutrients are not incorporated in the food chains of soil. Losses occur when the input of organic matter ceases, such as when deforestation or strip mining occurs and soil is damaged. In order for soil to be productive, there must be a continuous flow of energy in the form of carbon compounds through the soil organisms. Fresquez and Aldon of the USDA Forest Service (1984) noted that topsoil stored for years, and especially the mining overburden material, has little biological resemblance to the undisturbed surface soil and that the resulting reductions to the fungal genera and microorganisms result in an unstable and unbalanced soil ecosystem. Prolonged storage was also a part of the research conducted by Harris and Birch (1989). They concluded that prolonged storage intensifies the loss of the bacterial element of the soil.

Mycorrhizal fungi are a very important part of the microbial community. These fungi are often reduced or destroyed by stockpiling. Mycorrhizae fungi grow symbiotically with the roots of higher plants. The general beneficial effect of the micorrhizal condition on plant growth is one of improved mineral nutrition, specifically, enhanced nitrogen and phosphorus uptake. Mycorrhizal symbioses is also documented as protection against pathogenic fungi (Tate & Klem 1985).

An additional benefit to this symbiotic relationship, is how mycorrhizae hyphae form an extensive network in soil. These hyphae are covered with extracellular polysaccharides that form soil aggregates. These aggregates are held intact by the roots so that they do not collapse in water. This forms pore spaces and drainage channels. In a study, conducted in Derbyshire, England, of the relationship between aggregate stability and microbial biomass in three restored sites, a linear relationship was shown to exist between the health of the microbial community and the quality of soil structure (Edgerton, Harris, Birch, & Bullock 1995). The microbial community is responsible for the development of a soil structure conducive to the various biogeochemical cycles (Tate & Klem 1985). Deep stockpiles create both high and low moisture problems, which limits soil microbial respiration. To maintain a healthy microbial community, soil moisture must have some constancy in order for fungal propagules to survive.

Refining Soil Stockpiling Practices: Stockpiling techniques, and the wholesale removal of the topsoil layers, reduce the chances for succession for much of the pre-existing vegetation. Plant fragments from pre-existing vegetation are lost or greatly reduced. The seed bank is also reduced, and what does remain must compete for the reduced nutrients with microbes. These microbes become highly competitive as the base of stockpiles become anaerobic.

In addition to a loss in the breakdown of organic matter, stockpiling causes many other deleterious changes including a marked drop in the earthworm population (Johnson et al 1991) which affects soil nutrients, bulk density and water holding capacity. Stockpiling effects the restoration/reclamation efforts in mining operations. In order to mediate some of the damages caused by stockpiling, new and revised techniques are being used. One technique to mediate soil damage in stockpiling involves minimizing the depth of stockpiles. For optimum survival of mycorrhizal propagules, the depth of stockpiles should be restricted to the rooting depth of covering vegetation (Tate & Klem 1985). If plant cover can be maintained with roots extending throughout the depth of the stockpile, nutrient cycling processes and microbial activity can continue while the stockpile is stored. Depth is important, but the duration of storage is also a major factor in maintaining soil health and productivity.

Soil Erosion: Soil erosion is the removal of top soil by agents such as wind and water. Without human activities, losses of soil through erosion in most areas would probably be balanced by the formation of new soil. In forests and grasslands vegetation protects the soil.
When rain falls on the surface of grass or on the leaves of trees, some of the moisture evaporates before it can reach the ground. Trees and grass serve as wind breakers, and a network of roots help to hold the soil in place against the action of both rain and wind. Mining involves deforestation which destroys the protective canopy of vegetation and greatly speeds up erosion of soil.
The soil erosion can be prevented by extensive afforestation practices. This involves planting of trees on bare lands and nearby fields.
Types of Soil Erosion: *Erosion takes many forms owing to the effects of climate, topography, land use, groundcover and the erodibility of the soil type. The main types of erosion are:*

(i) Rain Splash Erosion: *Erosion due to the impact of raindrops blasting soil particles from the soil surface. Particles can then be transported easily by sheet and other erosion types.*
(ii) Rill Erosion: *Removal of soil from surface whereby small channels rills up to 300 mm deep are formed. These form where run-off concentrates into depressions caused naturally or by wheel tracks.*

(iii) Tunnel Erosion: *Tunneling occurs when infiltrating rainwater or overland flow causes subsoil's to disperse, leading to subsurface piping and erosion. Dispersive soils particularly the strongly sodic Sod sols are especially prone to tunneling. If the topsoil collapses, sinkholes and gullies can form. Once tunnels have formed they are difficult to control and severe cases will need repro filing.*

(iv) Gully Erosion: *Gully erosion involves the removal of soil from the surface and sub surface caused by concentrated run off eroding channels greater than 300 mm deep.*
(v) Sheet Erosion: *Sheet erosion involves the removal of shallow, uniform layer of soil from the surface. It is often difficult to see as no channels are formed, with the down slope accumulation of eroded material being the only indication.*

Erosion Control
Progressive rehabilitation should be undertaken to stabilise disturbed areas as quickly as practical to limit erosion. Erosion and sediment control measures should be employed. The design parameters for the construction of erosion control work such as rock armored or grass lined waterways should be in accordance with established principles for engineering and soil conservation earthworks. A number of variables must be considered, such as time of concentration, rainfall intensity, erosivity, gradient, scour velocities and flow estimations. The erosion control options that may be employed throughout the life of the Project are as below :

Erosion control and cleared land.

- *restrict clearing to areas essential for the works*
- *windrow vegetation debris along the contour*
- *minimize length of time soil is exposed*
- *divert run-off from undisturbed areas away from the works*
- *direct run-off from cleared areas to sediment dam*

Exposed Subsoils

- minimize length of time subsoil is exposed
- direct run-off from exposed areas to sediment dam (s), use erosion control measures such as: bonded fibre matrix, composite blankets, erosion control blankets, gravelling, mulching, revegetation , soil binders and surface stabilizers, surface roughening, sediment fences, check dams, grass filter traps, rock filter traps, compost/mulch berms, drop inlet protection, gypsum application on exposed sodic soils.

Contour cultivation: All cultivation used to prepare the rehabilitation area should be on the contour. On steep slopes, this approach requires the land to be terraced or benched.

Contour Deep Ripping or 'Contour Furrowing': These procedures should be used to relieve soil compaction and improve water infiltration on exposed sodic subsoils and the Sodosol topsoil stockpile. These actions should be undertaken in conjunction with gypsum application.

Contour or Levee Banks : Earth mounds or similar structures are the most common physical control measures. The size of these structures is determined by the size of their catchment area. These structures should not be constructed out of dispersive or highly erodible materials.

Absorption and Pondage Banks : These banks are similar in design to contour banks but laid out such that they pond water - thereby causing greater infiltration and less run-off. They are applicable only to low slopes (less than 1%) and should be avoided in materials which become dispersive when saturated. They should not be used on spoil dumps.

Diversion Banks: These banks are commonly used to reduce or eliminate the catchment to the heads of gullies. They need to be located such that they spill water to stable areas - preferably away from the rehabilitation area.

Spillways/Grassed Waterways: These structures are used to confine run-off from any or all of the above structures into a stable vegetated flow path. Because these structures effectively take all excess run-offs from a rehabilitation area, they should be installed first and well vegetated prior to the actual construction of the diversion structures. However supplementary irrigation water may be required to sustain the vegetation.

Lined Waterways : Additional treatment and special precautions may be required to protect waterways from erosion. The on-site suitability of the following available treatment measures will be made:

- jute mesh may be used to line channels
- rip-rap or stone pitching involves the use of stone
- concrete filled bags with an underlying filter blanket of sand and gravel
- gabions and mattresses (rockfilled wire baskets)

Sedimentation Dams -Gully Trap Dams: These structures are an interim measure to confine the movement of soil to the rehabilitated area. In effect they act as settling areas to ensure that soil eroded from the rehabilitated area does not pass beyond that area. Ideally their role in erosion control should diminish over time as the rehabilitated area is stabilised by other measures.

Sodosol Erosion Control: Gypsum should be applied to Sodosols to improve aggregate stability (gypsum displaces sodium ions with calcium ions). Where practical, half the recommended dosing rate will be applied to the surface of the soil material prior to stripping. The other half should be applied to the top-dressed material immediately after spreading. Alternatively gypsum will be applied to the soil surface after its spreading and incorporated into the soil by ripping. The use and quantities of gypsum will be determined on a site by site basis prior to topsoil stripping.

Aims of the Topsoil Handling Procedure :

To outline the requirements for effective topsoil management, including stripping, stockpiling and monitoring activities. Effective handling of topsoil is imperative to ensuring successful rehabilitation of disturbed areas. The aims of the Topsoil Handling Procedure, to ensure effective preservation of topsoil quality, are as follows:

- to define the appropriate suitability and stripping depth of soil material to be removed;
- to establish soil stripping requirements
- to ensure topsoil is properly stripped prior to land disturbing activities; and
- to minimize the potential for degradation of topsoil caused by mixing, compaction, rutting, or loss of organic matter;
- to determine the topsoil stockpile management requirements to preserve the topsoil quality through effective topsoil storage, minimizing re-handling, and maximizing availability of high quality topsoil for use in rehabilitation; and to describe the topsoil monitoring processes implemented.
- If topsoil is stockpiled prior to placement, the top 1 foot of the stockpile material should be mixed with the remainder of the stockpile to ensure that living organisms are distributed throughout the topsoil material at the time of final placement.
- A temporary soil stabilization and erosion control treatment shall be applied to the exposed top soiled areas to protect the topsoil prior to permanent seeding .The topsoil surface shall be left in a roughened condition to reduce erosion and facilitate establishment of permanent vegetation. The roughening establishes safe sites for seed to germinate and grow.
- Smooth slopes or surfaces are not acceptable.

SCOPE

The Topsoil Handling Procedure (THP) applies to all project activities that are likely to cause disturbance to existing topsoil and other suitable plant growth media within and outside of the Mine Lease area. This procedure should be implemented in conjunction with other management plans like Sediment and Erosion Control Plan; Waste Management Plan; Hazardous Materials Storage and Handling Guidelines; Interim Rehabilitation Plan; & Mine Closure Plan etc.

Guidelines for implementation of top soil handling procedure:

All personnel from top management to contractor companies involved in mining projects need to be aware of, and are required to abide by the Topsoil Handling Procedure. The responsibility of persons at different level of management should include the following:

- *Ensure the Topsoil Handling Procedure and its contents are communicated and enforced throughout the project lease area and its entire project life.*
- *Review and approve the Topsoil Handling Procedure.*
- *Ensure appropriate surveys are undertaken by employees or contractors prior to stripping.*
- *Designate areas for topsoil storage.*
- *Determine lengths and width of windrows of topsoil stockpiles.*
- *Ensure topsoil quality is analyzed in a laboratory approved by State Pollution Control Board.*
- *Provide job instructions for employees and contractors as per necessity with the purpose to raise environmental awareness and ensure effective operations of the workers involved in the earthworks.*

- *Review and amend the Top soil handling procedure (THP) with respect to legal compliance with International standards and Indian laws, Environmental clearance conditions, Consent to operate conditions, other regulations and standards.*
- *Communicate with the Mines Manager,Environmental Manager and Supervisor the legal requirements and amendments relevant to the subject.*
- *Ensure specialist advice on topsoil handling is communicated to Heavy Earth Moving Machineries (HEMM) operators and project managers.*
- *Ensure contractors are inducted on site requirements applicable in this plan.*
- *Verify topsoil is removed and stockpiled in accordance with the Top soil handling procedure (THP).*
- *Conduct regular inspections of topsoil stockpiles and ensure they are properly demarcated.*
- *Ensure soil is stripped and relocated in accordance with a particular work plan and as specified in the Land Development Plan for proposed works.*
- *Keep records on topsoil movement and storage.*
- *Perform topsoil stockpile quality monitoring & Communicate results of the topsoil quality monitoring with Regulatory authorities in a timely manner.*

Recommendations and Conclusions:
With all of its deleterious effects, topsoil stockpiling is still better than attempting to establish plants in the soils that exist below the topsoil layer. Recent research shows that anaerobic conditions and poor nutrient cycling result from deep stockpiling, especially stockpiles deeper than one meter. Studies also show that long-term storage is detrimental to soil health. New techniques are being used with varying rates of success. Mining companies involved in restoring mining projects need to be made aware of how long term storage and depth of stockpiles affect the soils' productivity. Standards for optimum size and shape of stockpiles need to be established. To improve soil productivity after stockpiling, staging techniques should be used.

Staging the project means that stockpiles are often re-spread in a very short timeframe, a few months or less. If mining operations could be staged in a similar manner, it is possible some of the effects of long term stockpiling could be reduced. Another challenge in mining that use stockpiling is in the use of heavy equipment to remove and replace topsoil. Use of heavy equipment results in compaction, however there is no other way for moving the large amounts of soil to be stockpiled.

In conclusion, in order to achieve site stabilization, minimize degradation, and facilitate the long-term recovery of the mining projects with an aesthetically pleasing landscape, an understanding must exist that the successful recovery of these sites is dependent on soil quality. Topsoil stockpiling is a valuable technique, but restoration plans must be guided by research so that the soil that is re-spread back onto these sites is productive.

Availability of land for top soil storage is a big problem, considering the huge land requirement for storage of top soil and overburden specially in mines where stripping ratio is very high. The option of transportation and storage of top soil on degraded forest lands, which are likely to be used for afforestation may be considered. After all we are disposing of hazardous waste at far off site at considerable cost to prevent the contamination of soil, in the same way top soil should also be preserved by specialized agencies and should be stored at degraded areas in the nearby places outside lease area of the mine, so that the precious top soil is saved. Though at times, the cost may seem prohibitive, but considering the scarcity of good top soil, the cost may remain the sole criteria.

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