Ecosystem Recovery in Mine Spoils of India

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Abstract

Recovery of any degraded ecosystem is a painstakingly slow process with success never guaranteed. In case of coal spoils the problem is even more acute and depends on a large number of external and internal factors.

The most commonly employed criteria for judging the success of an ecosystem reconstruction program is simply whether or not the reconstituted community resembles the original : does it contain the same dominant species and have similar physiognomy? But superfluous comparison more often than not prove deceptive, when, in the long run, the recreated community fails to sustain itself and disintegrates. The success of ecosystem recovery can be judged by sustainability, invasibility, productivity, nutrient retention and biotic interactions.

Substrate supply and microbial population regulate organic matter mineralization rate in the early phase of soil redevelopment. Thus microbial bio-mass and microbial activity play an important role in nutrient cycling. Due to the recalcitrant nature of mine spoil microbial immobilization and nitrogen transformation rate in the soil is adversely affected.

In the current study an attempt has been made to assess ecosystem recovery of Indian coal mine spoils in terms of microbial activity and nitrogen transformation rate in the soil.

Key words : nutrient, sustainability, mineralization, immobilization, recovery, reclamation

INTRODUCTION

Surface mining operations have the potential to destroy the flora and fauna, and contaminate the soil, air and water in the surrounding areas (Safaya, 1979; Dhar and Thakur, 1995). In recent years, increasing emphasis on opencast method of excavation has resulted in unprecedented increase of waste dumps in India. Mine spoils pose adverse conditions for soil microbe and plant growth, due to its low organic matter and other essential nutrients and unfavourable soil chemistry, poor structure - either coarse or compact, and high isolation from vegetation (Meyer, 1973; Harthill and Mckell, 1979). Poor microbial population inhibits nutrient transformation the establishment of the plant growth and the process of ecological succession (Singh et al, 1996). Consequently the natural recovery is a slow process and takes several years for the creation of self-sustaining ecosystem.

The overburden is in disequillibrium due to the destruction of the balance between landforms and soil erosion rates. Further both ground water and surface water resources are usually disrupted during mining. According to Harthill and Mckell (1979), when mining disturbs geology-soil-plant stability circuit, ecological chaos takes place. The effect of soil disturbance are markedly adverse because many beneficial soil characteristics may require from hundreds to ten of thousands of years to develop through pedogenic processes in order to reach a steady state resulting in maximum productivity (Jha and Singh, 1992). According to UNEP (1993) about 163 million hectares, half of India's total area has some degree of degradation. This is of great concern to both the public and government agencies because of their local impacts on ecosystems. Therefore in this study an attempt has been made to evaluate the natural ecosystem recovery in coal mine spoils of India.

TECHNOLOGICAL PROBLEMS

Technology for mined out wasteland reclamation is very complex and site or mine-specific. Pre-mining trials of the earmarked areas for reclamation should be undertaken by

estimating the overburdens and tailings and, also, there should be a record and stock for the existing species. Establishing the vegetation on these sites is generally difficult because of altered pH, variable texture, lack of organic matter, fragmented rocks and many other adverse biological and toxic-chemical factors. Management of this problem involves inter-disciplinary professionals because it is a site-specific process and depends upon geology, geography, land use pattern, climate and the soil characteristics of the area. Integrated biological and mechanical practices can make successful reclamation possible. Methods for developing these areas with the plant species, which had existed before mining, or species, which have wider range of tolerance to such sites, should be considered.

For suitable, successful vegetative cover, the soil or overburden may require alteration of both physical and chemical properties. However, nutrients of the waste dump play a crucial role during the vegetation succession. Proper vegetative cover from natural vegetation is also essential. Species, which can be planted as intermediates may function as a nurse-crop and also improve the soil.

MATERIAL & METHODS

The study sites are located in the Khudiya river basin. The basin is located between latitude 23^0 41' to 23^0 47' north and longitude 86^0 17' to 86^0 26' east. Khudiya a tributary of Barakar river (largest tributary of Damodar River) originates from the Tundi hills. At most places the crystalline and Gondwana area are crisscrossed by post Gondwana multi-directional faults and lineaments. Soil is of red and yellow loam sedimentary types. They have a tendency of laterisaion, are highly leached, neutral to slightly acidic in reaction, deficient in organic matter, nitrogen and available phosphoric acid but potassium content is high.

Khudiya river basin represents tropical climate with hot summers and cold winters. May is the peak of summer with an average maximum temperature of 43 ^{0}C and minimum of 30 ^{0}C. While December and January are the coldest months with temperature falling upto 4 ^{0}C. Annual rainfall over the basin varies between 765 - 1607 mm with an average of 1200 mm of which 80% occurs during the monsoon. Wind direction during the first quarter of the year is east-west, while in second quarter it is north east to south west, during third and fourth quarter it is south easterly and north easterly respectively. Wind speed over the basin being about 105 km/h (maximum) during summer and 10.8 km/h (minimum) during winter.

The floral biodiversity of the Damodar river basin is rich and represented by 137 flowering plant families and 853 species belonging to 535 genera. Poaceae is the prominent family of the region with 108 species followed by leguminaceae with 92 species. There are 24 species of large and small mammals, 17 species of reptile and about 300 species of birds represented the faunal biodiversity of the basin.

The soil sampling is done on a series of coal spoil dump, aged 0, 5, 10, 16, 20, 24, 30 year exhibiting more or less same physical, geographical and climatic condition in the Khudiya river basin.

10 samples were collected randomly from each spoil from the upper 10-cm soil. The field moist soil was sieved (<2 mm) and again mixed in equal proportion before the estimation. The every sample divided into three parts. First part in the field moist condition was used for the determination of pH, nitrate as nitrogen, Electrical conductivity, potassium content and phosphorous content. The second part (field moist) was used for assessing the nitrification rate. The remaining part of soil sample was used for the analysis of water holding capacity, bulk density and moisture content.

Nitrification rate was measured by a buried bag technique, as described in Eno 1960 and Singh et.al.1991. NO_3^-N were determined at time zero and after 30 days of field incubation. The increase in NO_3^-N during incubation is referred to as nitrification.

RESULTS & DISCUSSION

The zero year coal spoil have bulk density just 74% and 75% of wood land and farm land soil respectively. In the coal spoils it increases with the age. Coal spoil has moisture content just 54% of woodland and 51% of farmland

soil. The zero year coal spoil have very low water holding capacity as it is just 61% and 58% of wood land and farm land respectively. The water holding capacity gradually increases as the dump becomes older.

The pH of the region varies in between 5.4 - 7.1. Conductivity of zero year coal spoil is just 51% and 57% of woodland and adjacent farmland soil respectively. The potassium content of zero year coal spoil is just 62.4% and 68% of woodland and farmland soil respectively while phosphorus is 29% and 32% respectively. Nitrogen as nitrate is ranging 1.53-3.79 kg/ha in the case of coal spoils. While it's 3.65 and 3.34 kg/ha in case of woodland and farmland respectively. The trend of nitrate nitrogen in coal spoils increases with age.

Nitrification rate of coal spoils ranges in between 15.37 to 31.72 kg/ha/yr. The rate of nitrification in coal spoil is identical to farmland in approximately 24 years and its identical to woodland in 43 years**.** The average increase in nitrifying capability of coal spoil is 0.545 kg/ha/yr.

Nutrient recovery is the most important aspect to achieve rehabilitation of wasteland. It includes use of an appropriate reagent for stabilization or fertilization of the mine wasteland. Application of Nitre, Ammonium, Phosphate, Calcium or Sodium lignin-sulphonates (waste product of paper manufacture) are among the cost-effective method to provide a crust resistant to wind and water erosion and also helps in the process of nutrient recovery for the uptake of plants. Some of the waste products that can be utilized are as given in **table 1**.

The exact status of disturbed ecosystem can be deduced by comparing it with an undisturbed local ecosystem. The most important nutrient required by producers is nitrogen. And nitrate is the precious available form of nitrogen to plant. Hence apparently the transformation rate of nitrate in soil can be a marker in the case of ecosystem recovery. The first step in any restoration strategy of course is to protect the disturbed habitats and communities from being furthered wasted and from loosing the extent genes, (Singh & Jha 1993). Restoration success depends on the argumentation of the biological activity of the surface soil horizons in the long term, (Arnold et.al 1984). Available carbon source is a critical factor stimulates micro-flora in mine spoils, (Fresqurez & Lindemann 1982, Srivastava et.al 1989).

As stated by Whifeford (1988) restoring Nitrogen cycle is one of the major goals of ecosystem recovery in these disturbed environments. The ultimate fate of nitrogen in Nitrogen cycle is nitrate. But the magnitude and size of the pool involved controls the fate and form of soil nitrogen. Denitrification of nitrate into nitrogen and immobilization depends upon the availability of nitrate hence practically it is difficult to estimate them. Instead of these factors the nitrification rate depends on the microbial activity and the existing state of the “sere”. It is more convenient to emphasize on the net nitrification rate only to estimate the restoration process at a time because availability of nitrate (one of nutrients) determines the “sere” and vice versa. Again any further evolution in ecosystem greatly supported by the availability of nutrients. Once nutrients transformed, if plants are present to utilize them there is very less possibility to transform back the same nutrients. One important non-biological event in the nitrogen cycle is nitrate leaching because of its negative charge. Nitrate is not strongly observed by soil colloids as ammonium ions and is highly mobile within the soil liquid phase. It is more convenient to concentrate only on the net nitrification rate to estimate the restoration process.

CONCLUSION

As the net nitrification rate is concerned the coal spoil took approximately 24 year to recover it self as the farmland /grassland ecosystem and 43 years to woodland. Since the mining work initiated in the area were preexisting woodland is destroyed the wining activity pushes back the ecosystem 43 years back. Only fact goes in the favor of this mine spoil that they have acidic pH which supports the microbial activity for mineralization. The accumulation of soil nitrogen to a critical level is needed for subsequent recovery for colonization of the vegetation on the spoil. Direct seeding for re-vegetation of coal spoil

may be favored because this is easier and cost effective then planting but careful after care is essential plants with nodule and mycorrhizal association allowed both increased phosphorus up take and nitrogen fixation.

The primary approach for recovery of coal spoil is to control of erosion through plant cover in the short term and the development of a self sustaining community through colonization of native plant in the long term. The problem of accelerated recovery in coal spoil may be partially solve by a step wise time bound restructuring of vegetation and manipulation of nutrient cycling rate by sustainable resource use.

ACKNOWLEDGEMENTS

The Ministry of Environment and Forests and the Department of Land Resources, Ministry of Rural Development, Govt. of India, New Delhi, are gratefully acknowledged for the financial support for the study.

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Table 1 : Use of waste products as an input in restoration of wastelands

Material	Composition(%)				Special problems
	Organic matter	N	P	K	
Farmyard manure	24	0.6	0.1	0.5	Toxic when applied raw on plants
Pig slurry Poultry manure	3	0.2	0.1	0.2	High water content
Boiler ash	68	2.3	0.9	1.6	High levels of ammonia
Sewage sludge (air dried)	45	2.0	0.3	0.2	Possible toxic metals higher moisture content.
Mushroom compost (dried)	95	2.8	0.2	0.8	High lime content
Municipal waste	65	0.5	0.2	0.3	Miscellaneous objects
Straw	95	0.5	0.1	0.8	Adverse C/N ratio
Colliery spoil	0	0.03	0.04	0.4	Possible high levels of pyrite causing acidity