Soil Environ. 33(1): 38–42, 2014
www.se.org.pk
Online ISSN: 2075–1141
Print ISSN: 2074–9546

Soil chemical properties in an age series of restored mined land- A case study from Uttarakhand, India

Shikha Uniyal Gairola*
Department of Environmental Science, Uttaranchal College of Science and Technology, Dehradun, India

Abstract

Present study was carried out in an ecorestored rock phosphate mine at Maldeota area of the Dehradun, Uttarakhand, India where ecorestoration measures were undertaken in 15 hectare mine soil area during the year 1982 by Forest Research Institute in collaboration with Pyrites Phosphate Chemical Limited (PPCL). The objective was to understand chemical changes, which took place in an age series of 23, 22, 21 and 20 years old mine restored sites rock phosphate mine and an adjoining natural forest was also studied for comparison of soil chemical properties. All the data was analyzed by using the Statistical Package for Social Science Program for Windows version 15.0. Multiple comparison and two way analysis of variance (ANOVA) procedures were used to compare differences among samples. The Least Significant Difference (LSD) test was performed to determine the significant differences among sample means at $p < 0.05$. Increase in all the nutrients has been observed during the study period. A significant difference ($p < 0.05$, $p < 0.01$, $p < 0.001$) has been recorded on an average in the amount of nutrient (kg ha^{-1}). As the mining of minerals leaves behind the overburden dumps and infertile soil, the restoration efforts help in regaining the biodiversity and ecosystem services.

Keywords: *Ecorestoration, natural forest, nutrients, restored sites*

Introduction

Himalayas are very rich in mineral resources like marble, limestone, gypsum, dolomite and rock phosphate but the fact that very low carrying capacity of these hills have overlooked. No doubt, mining of these minerals from the Himalayan region is important not only for the local and national economy but also for the development of industry as well, but the extraction of these minerals is bringing about superimposition of natural fertile soil by inactive and infertile materials. Any neglect or mismanagement that results in ecological disturbances in the Himalaya will, therefore, necessarily threaten not only this region, but also have catastrophic long-term impacts on the downstream plains and consequently the whole country. A proper management of this young, unique and fragile mountain system, long delayed, incorporating the twin objectives of the environmental conservation and sustainable development, cannot be postponed further. Hazardous activities start right from clear felling of vegetation for mining and allied activities that accentuate as the operations increase in intensity (Soni and Vasistha, 1985). Loss of soil productivity, biological diversity, health and environmental hazards due to air, water and noise pollution microclimatic changes etc. are some of the associated problems of these processes. Such areas are thus posing a great challenge for ecologists, biologists, agriculturists, engineers, soil scientists and foresters who are invariably concerned about restoration of the disturbed ecosystem. A suitable reclamation program on scientific lines is thus urgently required.

Mining activities generate a large amount of waste rocks and tailings which deposit at the surface of recipient soil. The land surface is damaged and the waste rocks and tailings are often very unstable and become sources of pollution. After environmental degradation, restoration and reclamation efforts can be hampered by poor physio-chemical soil characteristics and decreased soil biology complex. To enhance degraded system recovery, soil manipulations seem necessary to alleviate habitat destruction (Ohsowski *et al.*, 2012). The original soil of mine degraded lands is usually lost or damaged, with only skeletal materials. There is commonly lack of organic matter and its associated nutrients such as nitrogen (N) in most degraded land materials. Organic matter provides a continuous source of nutrients, e.g., it provides most of the N reserve in soils and comprises typically 5% N which is mineralized at about 2% per year (Harris *et al*., 1996).

Reclamation of these disturbed mine lands, includes management of all types of physical, chemical and biological disturbances of soils such as soil pH, fertility,

*Email: shikhaa.fri@gmail.com

microbial community and various soil nutrient cycles those make the degraded soils productive. Revegetation constitutes the most widely accepted and useful way to decrease erosion and protect soils against degradation during reclamation. Once the reclamation plan is complete and vegetation has established, the assessment of the reclaimed site is necessary to evaluate the success of reclamation.

This paper focuses on the chemical properties of mine soil in an age series of restored rock phosphate mine of the Doon valley and also includes comparison between chemical properties of mine soil and the natural forest.

Study area

The Doon Valley is a characteristic geomorphological entity of the Himalayas and is significant for the natural resources particularly the minerals, soil, forest and water. The mineral wealth in the region is found in the form of high grade limestone, marble, gypsum, dolomite and rock phosphate. Mining of rock phosphate was initiated in this area by Pyrites Phosphate and Chemicals Ltd. (PPCL) during the year 1960. The mining of these valuable minerals has defaced this picturesque valley leading to many ecological and socioeconomic problems. The present study has been undertaken in restored area of rock phosphate mine at Maldeota located in the Dehradun District, Uttarakhand, India. The Maldeota has an elevation ranging from 650 m to about 1050 m above mean sea level. It is situated in the north east of Dehradun at a distance of about 18 km on the west bank of perennial river Bandal. The area affected by open cast mining was about 15 ha till 1982 when ecorestoration was initiated. Ecological rehabilitation of this rock phosphate mine site has been done by using different technical and biological methods in a phase wise manner. Soil chemical properties have been studied between different ages of restored site i.e. 23 years old restored site (site1), 22 years old restored site (site 2), 21 years old restored site (site3), 20 years old restored site (site 4) and adjoining natural forest (site 5) for the period of two years. Five replicates were laid in each restored site and natural forest.

Materials and Methods

Soil samples were collected in the month of October 2005-06 and 2006-07, randomly from all the five sites. In each site five quadrats were laid and sample was collected from each quadrat. For collecting samples, top layer of undecomposed litter was removed and samples were collected from the depth of 0-30 cm in each case. Chemical properties of soil samples were estimated as follows:

Organic matter was estimated by Walkley and black method (Jackson, 1973), total nitrogen was estimated by Kjeldahl method (Wilde *et al.*, 1985), available nitrogen was determined by Kjeldahl method (Wilde *et al.*, 1985), available phosphorous was determined by Olsen *et al.* (1954) using colorimeter and ammonium acetate extractable K was estimated by using Flame photometer according to Misra (1968). Exchangeable Calcium (Ca) and Magnesium (Mg): was determined by leaching the soil with normal ammonium acetate and then estimating the calcium content in the leachate by titrating with EDTA (Black, 1965). Exchangeable magnesium was estimated by Spectrophotometer (Black, 1965). The results were then subjected to statistical analysis using two - way analysis of variance.

Results and Discussion

Organic matter

The highest organic matter was calculated for site 3 (26218.2 kg ha^{-1}) while site 2 accounted for the lowest organic matter (23914.8 kg ha^{-1}). The value of organic matter (Table 1) was in the decreasing order of site 3 > site 1> site 5 > site 4 > site 2.

Total nitrogen

The difference in total nitrogen was highly significant (Table 1) in different restored sites ($p < 0.001$). It was found that level of total nitrogen in Site 3 was the highest (1065.6 kg ha^{-1}) followed by Site 5 (948.15 kg ha^{-1}) while it is the lowest at site 1 (545.46 kg ha^{-1}).

Available phosphorous

Available phosphorous was maximum at site 4 (24.41 kg ha^{-1}) while minimum was at site 5 (4.54 kg ha^{-1}) (Table 1). Statistical analysis revealed that differences among the sites were highly significant ($p < 0.001$).

Exchangeable potassium

It was found that level of potassium at site 5 was the highest (57.90 kg ha^{-1}) during both the years of study while it was the lowest at site 2 (32.41 kg ha^{-1}).

Exchangeable calcium

Exchangeable calcium was maximum (Table 1) at site 4 (2681.28 kg ha^{-1}) while minimum exchangeable calcium was at site 5 (2033.46 kg ha^{-1}). Variation among the sites was highly significant ($p < 0.001$).

Exchangeable magnesium

Exchangeable magnesium (Table 1) was maximum at site 2 (304.85 kg ha^{-1}) while was minimum at site 1 (198.20

kg ha^{-1}). Variation among the sites was highly significant ($p < 0.001$). Being a rich source of nitrogen, phosphorus, potassium and other mineral elements, high levels of organic matter in soils play a major role in regulating plant nutrient levels in soil with low fertility (NRC, 1981; Davis *et al.*, 1995). The organic matter also supports the growth of decomposers and symbiotic microbes which supply nutrients to growing plants and may even provide protection from pathogens (Chanway *et al.*, 1991).

under plantations of five exotic tree species (*Casuarina equisetifolia*, *Gravellia pteridifolia*, *Eucalyptus hybrid*, *Cassia siamea*, *Acacia auriculiformis*). The data obtained were compared with those of the bare overburden mine soil and the native forest soils. The results showed an improved soil nutrient status under different plantation stands compared to bare overburden. Organic carbon and total nitrogen concentrations were higher in the plantation stands in comparison to the bare overburden dumps. The plantations enhanced the nutrient status of the degraded mine spoil land. The plant species varied in their ability to modify the soil properties of mine spoil (Dutta and Agrawal, 2002).

Table 1: Mean and standard deviation of some selected chemical properties in different ages of restored sites and adjoining natural forest

Site	Soil Nutrients (kg ha^{-1})						
	Total N	**Available N**	**P**	**K**	**Ca**	**Mg**	**OM**
Site 1	545.16±47.98	53.89±6.36	12.10±0.93	34.41±1.68	2259.18±202.7	198.19±16.21	26103.0±5405.56
Site 2	665.76±31.87	67.44±3.05	9.11±0.71	32.41±2.19	2557.92± 86.03	304.84±17.17	23914.8±3495.91
Site 3	1065.6±59.95	106.18±12.23	7.41±0.55	57.90±4.33	2104.56±302.34	238.87±17.14	26218.2±4640.17
Site 4	922.35±31.75	94.44±7.31	24.41±5.34	39.89±4.53	2681.28±128.75	285.28±43.05	24624.6±4341.33
Site 5	948.15±95.77	95.68±6.02	4.54±0.52	32.63±2.39	2033.46±116.62	279.15±16.10	24673.9±3551.6
Significance	***	***	***	***	*	***	NS
CD	0.0027	0.0268	0.0012	0.0015	0.0298	0.0114	-

The data represents the mean value of five replicates.± standard error,^{NS} Non significant, ***($p < 0.001$), ** (($p < 0.01$), * ($p < 0.05$)

It was found that the organic matter in the restored site was higher (23914.8 – 26218.2 kg ha^{-1}) compared to the natural forest (24673.9 kg ha^{-1}) (Table 1). This seems because the natural area was highly degraded (Kumar *et al.* 1984). Generally, a large pool of organic matter in soils improves the structure and water holding ability, stabilizes the surface and provides considerable nutrients from biodegradation to supply the requirements of the ecosystem. Pietrzykowski (2005) studied reclamation of forest ecosystem developed on sand mine cast in the Southern Poland and found similar results of organic matter.

Several investigators have reported the nitrogen accumulation as major factor limiting the rate of vegetation development (Roberts *et al.*, 1981). Total nitrogen (Table 1) shows that total nitrogen in the restored site ranged between 545.16 – 1065.6 kg ha^{-1} while in the natural forest, it was 948.15 kg ha^{-1}. Lack of mineralizable organic nitrogen and lower mineralization rates affect the availability of N to plants in mine soils. In the present studies, slightly higher total nitrogen has been found in restored sites in comparison to the natural forest area. This may be due to high organic matter accumulation in restored area by roots and leaching of nitrogen from herbaceous vegetation of plots. The total nitrogen content in soil around different restored plantation is comparable to the results of Srivastava and Singh (1988) who found 0.78% total nitrogen in 12 years old naturally vegetated overburden. Dutta and Agrawal (2002) assessed the soil characteristics and microbial activity of vegetated coal mine spoil land

In the restored sites, available nitrogen ranged between (53.89 – 106.18 kg ha^{-1}) while in the natural area it was 95.68 kg ha^{-1}. Consequently, the amount of available nitrogen in the soil is very small. Masoodi (1998) studied an age related increase in available nitrogen content of reconstructed area. Due to restoration activities, the amount of nitrogen was found to be increased with the age of plantation. Factors such as pH, temperature of the soil, soil moisture and gas exchange and organic matter in any form available to microorganisms involved in the mineralization process influences availability of nitrogen. Mixtures of trees that include those capable of cation pumping can return cations to the surface in the form of fine litter, consequently influencing the availability of nitrogen in the restored mined lands (Kumar, 2008).

The data (Table 1) shows that available phosphorous in the restored area ranged between 9.11 – 24.41 kg ha^{-1} while in the natural forest it was 4.54 kg ha^{-1}. Restored mine area has slightly alkaline pH which is favourable for release of nutrients (nitrogen, phosphorous, potassium) and enhancement of microbial occurrence (Arnon and Johnson, 1942; Cummins *et al.*, 1965) and this may be one of the reasons for higher available phosphorous in restored mine area. Accumulation of organic matter due to the plantation activities has increased phosphorous content in restored site. Phosphorous of organic matter is converted into orthophosphate on mineralization.

In the present study, exchangeable potassium is higher in restored sites than that in the natural forest area (Table 1). The soil potassium is governed in soil mainly by humus and leaching effects. In the restored mine site exchangeable potassium ranged between 32.41 – 57.90 kg ha^{-1} while in the natural forest exchangeable potassium was 32.63 kg ha^{-1}. Due to the accumulation of organic material at restored site and better condition for leaching, higher potassium contents were observed in soils of restored areas compared to natural forest. Lindsay and Nawrot (1981) on the basis of their studies in coal mine areas have concluded that there is significantly greater potassium concentration in vegetated soil than in non-vegetated mine spoils. The increase in potassium in restored sites can be attributed to the process of weathering that breaks or open up the rock structure. The humification of organic matter involves many chemical reactions which tend to release exchangeable potassium readily from K-minerals (Masoodi, 1998).

The concentration of calcium and magnesium was higher in restored mine areas as compared to natural forest. Calcium in the restored site ranged between 2104.00 – 2681.28 kg ha^{-1}. Similarly, magnesium in the restored site ranged between 198.19 – 304.84 kg ha^{-1} while calcium and magnesium in the natural forest was 2033.46 kg ha^{-1} and 279.15 kg ha^{-1}, respectively, (Table 1). The present results are supported by Indorante *et al*. (1981) who found that exchangeable calcium and magnesium in the newly constructed soil were higher than those of the undisturbed soils.

Conclusion

There was an overall increase in soil nutrients in the restored sites as compared to the natural forest. Analysis of soil from restored mine sites showed marked improvement in their properties with the age of bio-restoration. The accumulation and subsequent decomposition of plant residues has resulted in building the organic matter with an associated increase in nutrient enrichment. Soil fertility is a major factor, which regulates plant growth. A rich soil supports healthy crop while the vegetation helps in improving the soil by adding organic matter, returning nutrients and promoting microbial activities. The basic goal of restoring a mine site is to restore its productivity. As a part of this study, a similar effort was made to assess the improvement in the chemical properties of soil in restored mined area after 23, 22, 21 and 20 years of restoration.

Ecological restoration in areas of mined land can help reverse global biodiversity losses. The recovery of ecosystem services, such as healthy waterways and pollination, can also be promoted. Ecological restoration is widely used to reverse the environmental degradation caused by human activities such as deforestation, pollution and land use techniques that cause soil erosion, although different kinds of ecosystems recover at different rates. Thus there is the urgent need of effectiveness of restoration actions which increases provision of both biodiversity and ecosystem services. In this context, mined area restoration is essentially useful as they are increasingly viable under emerging payments for environmental services schemes like the Reducing Emissions from Deforestation and Degradations (REDD) mechanism proposed for a post-Kyoto climate agreement. Such initiative will compensate developing countries for protecting and restoring ecosystem; could simultaneously deliver benefits to the environment and local communities.

References

Arnon, D.I. and C.M. Johnson. 1942. Influence of hydrogen ion concentration on growth of higher plants under controlled condition. *Plant Physiol*ogy 17: 525–539.

Black, C.A. 1965. Methods of Soil Analysis. Part 1 and 2. American Society of Agronomy, Madson, Wincosin, USA.

Chanway, C.P., R. Tukkington and F.B. Holl. 1991. Ecological implications specifity between plants and rhizosphere microorganisms. *Advanced Ecological Research* 21: 121–169.

Cummins, D.G., W.T. Plass and C.E. Gentry. 1965. Chemical and physical properties of spoil banks in the eastern Kentucky coal fields. Central States For. Exp. Sta., Columbus, OH. 11p.

Davis, J.G., L.R. Hossner, L.P. Wilding and A. Manu. 1995. Variability of soil chemical properties in two sandy dunal soils of Nigeria. *Soil Science* 159: 321–330.

Dutta, R.K. and M. Agrawal 2002. Effect of tree plantation on the soil characteristics and microbial activity of coal mine spoil land. *Tropical Ecology* 43: 315–324.

Harris, J.A., P. Birch and J.P. Palmer. 1996. Land Restoration and Reclamation. Principles and Practices. Longman, London (UK).

Jackson, M.L. 1973. Soil Chemical Analysis. Prentice Hall Ltd., New Delhi, India.

Kumar, O., H.B. Vasistha and P. Soni. 1984. Phytosociology and standing crop biomass of five different forest types of East Dehradun Forest Division. *Indian Forester* 110(8): 791–801.

Kumar, V. 2008. Floristic diversity and resource availability along the altitudinal gradient in Western Himalaya. Thesis submitted to H.N.B. Garhwal University, Srinagar, Garhwal.

Lindsay, R.E. and J.R. Nawrot. 1981. Evaluation of natural revegetation of problem spoil banks. p. 367-375. *In:* Symposium on Surface Mining Hydrology, Sedimentology and Reclamation. 7–11 December, 1981, Lexington, Kentucky, USA.

Masoodi, T.H. 1998. Evaluation of role of native plant species in restoration of mine land ecosystem. Ph.D. thesis submitted to Forest Research Institute University, Dehradun.

Misra, R. 1968. Ecology Work Book, Oxford and IBH Publishing Co. New Delhi.

National Research Council. 1981. Surface Mining, Soil, Coal and Society: National Academy Press, Washington. D. C., USA. 233p.

Ohsowskia, B.M., J.N. Klironomosa, K.E. Dunfieldb and M.M. Harta. 2012. The potential of soil amendments for restoring severely disturbed grasslands. *Applied Soil Ecol*ogy 60: 77-83.

Olsen, S.R., C.V. Cole, P.S. Watanabe and L.A. Dean. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate Circular 939, USDA.

Pietrzykowski, M. 2005. Characteristics of selected features of arborescent vegetation in reclaimed areas and in areas left for succession as exemplified by experimental plots in the Szczakowa sand mine excavation. *Acta Agraria et Silvestria, Seria Lesna, Krakau* 43: 1–26. (in Polish, English summary).

Roberts, R.D., R.H. Marrs, R.A. Skeffington and A.D. Bradshaw. 1981. Ecosystem development on naturally colonized china clay wastes. Vegetation changes and overall accumulation of organic matter and nutrients. *Journal of Ecology* 6: 153–161.

Soni, P. and H.B. Vasistha 1985. Reclamation of rock phosphate mine at Maldeota. p. 418–424. *In:* Proceeding Recent Advances in Plant Science. M.R. Sharma and B.K Gupta (eds.). Dehradun, India.

Srivastava, S.C. and J.S. Singh. 1988. Carbon and phorphorous in the soil biomass of some tropical soils of India. *Soil Biology and Biochemistry* 20: 743–747

Wilde, S.A., R.B. Corey, J.G. Iyer and G.K. Voigt. 1985. Soil and Plant Analysis for Tree Culture. Oxford and IBH publishing Co., New Delhi, India.

Wischmeier, W.H. and J.V. Mannering. 1959. Relation of soil properties to its erodibility. *Soil Science Society of America Proceedings* 23: 131–137.