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COMPARATIVE STUDY OF PHYSICO-CHEMICAL PROPERTIES INFLUENCE THE SOIL QUALITY OF CHRONOSEQUENCE MANGANESE MINE SPOIL

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Abstract: Ultimate objective of ecological rehabilitation is to fasten the natural successional processes to enhance the biological productivity, soil fertility and regulation of biotic control over nutrient fluxes within reclaiming ecosystem. The present study is focuses on the comparative assessment of variation in physico-chemical properties in seven different age series in manganese mines overburden spoil in chronosequence from fresh mine spoil to forest soil (MB0,MB2,MB4,MB6,MB8,MB10, FS) in Kanther Manganese mines, koira, Sundargadh, Odisha, India. The soil textural analysis showed the increasing trend in clay and silt percentage while decrement was shown in sand percentage from MBO to FS. Decrement in bulk density with increase clay percentage shown the negative co-relation ($r = -0.97.8$; $p<0.01$). The stability of soil is maintained by increasing water holding capacity, moisture content in percentage that is reverse of bulk density. P^H of the soil is slightly acidic to neutral from 6.73 to 7.58 represents gradual improvement towards rapid reclamation. The organic carbon content and clay percentage are positively correlated by showing increasing trend from MBO to FS (0.126 ±0.001- 3.469 ± 0.099 & 4.33 ± 0.760 - 13.6 ± 0.933 respectively) represents development of vegetation and available micropore space for proper aeration. Gradual increment of soil nitrogen (TN) and available phosphorus (AP) from MBO to FS (0.003% - 0.214% to 9.33% – 14.927% respectively) shows gradual establishment of leguminous species and mycorrhizal colonisation. The variations in soil textural analysis along with other parameters have strong imputations as important bio- indicator for soil fertility status.

Key words – Manganese mine spoil, chronosequence, physico-chemical properties, bio indicator

I. INTRODUCTION

Emerging economies as India mostly accelerated mining activities that causes the unpleasant environmental conditions with extreme physico-chemical and biological impediments like low cation-exchange capacity, decreased water holding capacity, low available nutrients, poor organic matter and insufficient soil microorganisms [1] and ultimately leads to land degradation. The real problem of land degradation on open cast mine sites, which were either restored badly or restoration process has become stopped due to unseen natural or anthropogenic reasons (2,3,4).Vigorously mined land, disturbed with metal contaminants usually do not have the capability to possess sufficient surface soil for vegetation (5,6) which not only limited to the site but also expanded to the surroundings through acid mine drainage and tailings deposit [7].Long term exposure to metal contaminated mine spoil has been reported to disequilibriate the ecosystem structure and functioning through detrimental effect on microbial activity (8,9). Besides, short term exposures to noxious metals have also been reported to reduce the microbial activity [8]. Rapid rotations in plant species constituents and disturbances in equilibrium of ecosystem components like biotic and abiotic relationships are major limitations of mining activity.

Ecological restoration is defined as the process of assisting the repossession of an ecosystem that has been degraded due to natural or artificial causes [10]. This process includes regaining the ecosystem functionality and sustainability as well as ecosystem services that are socioeconomic and cultural. Mine reclamation involves practiciable activities and ameliorations to restore ecological integrity as well as equilibrium through sustainable development of ecosystem .The restoration of ecosystem in metal/ metalloid defilement site is a major environmental challenge across the World. Supplementation of top soil, organic reformation (biosludge, fly ash, diary waste etc.) and microbial ameliorations (application of Azotobacter, Rhizobium, VAM etc.) are some existing techniques for natural reclamations of heavily metal contaminated soils. Excess of metal pollutants lead to selective impediment which could have largely affects the

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constitution of microbial community structure and function [11] that ultimately influence the biogeochemical processes that has great role in maintaining equilibrium of environment (12,13).

India has second largest manganese ore reserve after Zimbabwe lead to in situ reserves of total 406 million tonnes out of which Odisha secured first rank in manganese production. The silvery white, hard brittle metal is an essential mineral resource access of which is potentially toxic to our living system. Manganese concentration in normal human body is10-11mg that are mostly found in liver, bone and kidneys and act as cofactor for number of enzymes. But long term exposure to this trace element creates severe threats to living system such as iron deficiency anemia, chronic liver disease, manganism. The physico-chemical properties of mine spoils has the capability to retard the soil forming process and plant growth[14]. The physico-chemical and biological properties of the restored soil were gradually ameliorate with reference to soil pH, EC, bulk density, porosity, N, P, K, organic carbon, soil microbes, etc [1]. Available nutrients immobilization by microbial biomass is appraised to be the nutrients conservation mechanism for tropical soil [15]. For quantitative assessment of soil degradation and reclamation, dynamics of microbial biomass pool can be considered as important soil quality indicators for quantitative assessment of soil degradation and reclamation. So, the purpose of the present study is to determine the impact of mining activities to be monitored through biological soil quality indicators. The effective monitoring using soil bioindicators makes the process simple and robust for periodic assessment and provide a significant insight into the circumstances of soil or any retrogression in soil functioning due to repercussion of land use practices.

II. MATERIALS AND METHODS

A. Soil sampling

Sampling was done by general methodology following the standard soil microbiological protocol [16]. Sampling site was divided into 5 blocks, and five soil samples were collected randomly from 0-15 cm soil depth by spading pits of (15 x 15 x 15) cm^3 size in each block and referred to as sub-samples, form composite sample by mixing thoroughly. These samples were obtained from each site in the month of January for analysis and subjected to sieving (2mm mesh size) for characterization.

B. Study site description

The present study was carried out at Kanther Managanese mines, Koira (geographical in location: between 85A° 20' 09.67 " east longitude and 21° 53' 45.34" north latitude), which is located in the revenue district of Sundargarh, Odisha, India. About 73.653 ha area out of total geographical area (14.796 ha) of koira was demarcated for mineralised area and 58.857 ha for non- mineralised area. The area is maintained by Rungta mines Ltd. and is situated away from the mean sea level (1,940 ft. altitude). The study site experienced an average annual rainfall in the past one decade was 748.6mm with the highest precipitation in august when about 80% of the rainfall was received in the area during the SW Monsoon (June to September) every year. The mean annual temperature is 4.8 ° C in December and 47° in June.

C. Physico-chemical analysis

Estimation of Soil texture includes the clay (<0.002mm), silt (0.06-0.002 mm) and sand (2.0-0.06 mm) in percentage. Determination of Bulk density was done following the TSBF Handbook [17]. The moisture content and water holding capacity was done [18]. Measurement of soil pH (1:2.5 ratio of soil: water) was done using digital pH meter to know the acidity or basicity of overburden soil. Soil organic carbon estimation was done following Walkley and Black (Mishra, 1968) titration method. Total nitrogen content determined using Kjeldahl method [19]. Chloro-stannous reduced molybdophosphoric blue colour method [19] was followed for for measurement of available phosphorous content in different mine overburden spoil samples.

D. Statistical analysis

The simple correlation analysis was performed between different soil physico-chemical properties in seven different samples to test the level of significance using MINITAB Statistics 19.0 software.

III. RESULTS AND DISCUSSION

The degree of variability with respect to different soil physico-chemical properties across the sites was assessed to understand the direction of improving soil fertility. The textural analysis (sand, slit and clay) of chronosequences of manganese mine overburden spoil (Table 1) indicated an increasing trend in clay from 4.33% (MBO) to 13.06% (MB10), and slit from 7.6% (MBO) to 13.83% (MB10), but showed decreasing trends in sand from 85.9 % (MB0) to (MB10). However, the sand, slit and clay content in the near by NF soil were found to be 72.1%, 14.566% and 13.6% respectively (Table 1). The analysis of variance (two way ANOVA) indicated that the variation in textural composition of the manganese mine spoil with respect to seven different age series in chronosequence was estimated to be statistically significant ($p < 0.001$). Textural analysis showed a significant variation across the sites might be due to

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gradual accumulation of available nutrients supporting vegetation development and progressive improvement in soil structural stability and aggregation over time (20,21).

Bulk density was found to be maximum in MB0 (1.648 g/cm^3), but it showed a decline trend with the increase in age of mine overburden spoil and was found to be minimum in MB10 (1.233 g/cm^3) (Table 1). Higher bulk density in MBO may be due to lower clay content, nutrient deficient content and devoid of vegetation [22]. Besides, in fresh mines spoil plants unable to extend their roots effectively in high bulk density [23]**.** Due to increase in clay percentage and decrease in bulk density along with the sites lead to an improvement in soil aggregation [24]. Thus, estimation of BD regulates compaction of soil aggregates and measures the soil structure by determining the air and water availability to soil organism and act as indicator to show the aeration status of the soil (25,26) and showed a negative correlation with clay percentage (r = -0.97.8; p<0.01) (Table 2).

Table1. Physico-chemical properties in chronosequences of manganese mine overburden spoil [MB0, MB2, MB4, MB6, MB8, and MB10] as well as nearby forest soil (FS). (Values are mean ± SD; n = 3)

Parameters	MBO	MB2	MB4	MB6	MB8	MB10	FS
Sand (%)	85.9 ± 0.732	82.8 ± 0.862	80.9 ± 0.894	77.9± 0.694	73.9 ± 0.544	73.4 ± 0.404	72.1 ± 0.671
Slit (%)	7.6 ± 0.409	9.75 ± 0.483	10.566±0.450	11.3± 0.819	13.53±0.314	13.833±0.273	14.566±0.313
Clay (%)	4.33 ± 0.760	6.66 ± 0.422	8.9 ± 0.268	10 ± 0.322	12.2 ± 0.322	13.066±0.413	13.6 ± 0.933
BD(g/cm^3)	1.648± 0.007	1.583± 0.003	1.49 ± 0.003	1.32± 0.002	1.289±0.003	1.233 ± 0.001	1.189 ± 0.006
WHC (%)	28.942±0.499	32.877±0.850	35.171±0.658	40.757±0.969	43.575±0.674	45.829±0.083	54.581±0.845
MC(%)	6.494±0.210	7.496±0.127	7.720±0.101	8.819±0.129	10.261±0.8	10.720±0.180	11.535±0.072
pH	6.73 ± 0.015	6.856 ± 0.027	6.92 ± 0.008	7.00 ± 0.0186	7.32 ± 0.013	7.4 ± 0.008	7.58 ± 0.052
OC (%)	0.126 ± 0.001	0.312 ± 0.013	0.626 ± 0.1	1.247 ± 0.031	1.687±0.0431	2.048 ± 0.083	3.469 ± 0.099
TN(%)	0.003 ± 0.001	0.018 ± 0.008	0.036 ± 0.003	0.061 ± 0.002	0.086 ± 0.005	0.136 ± 0.014	0.214 ± 0.035
AP(mgP/kg soil)	9.33 ± 0.136	9.454 ± 0.084	9.759 ± 0.085	10.929±0.318	16.633±0.189	18.584±0.184	14.927±0.533

There is gradual improvement in hydrological regimes such as water holding capacity (WHC) and moisture content (MC) and showed reverse trend as compared to bulk density (BD) ranging from 28.942 % (MB0) to 54.581 % (MB10) and 6.494 % (MBO) to 11.535% (MB10) (Table1). Lower water holding capacity and moisture content in fresh spoil (MBO) as compared to MB10 may be due to positive domination of canopy cover in MB10 that restricts the heavy loss of water through evaporation from soil surface [27]. WHC shows positive correlation with OC (r = 0.990, p< 0.01), TN (r = 0.975, p < 0.01) and AP (r = 0.768, p<0.05) (Table 2). Textural composition and soil organic matter are the key component which influence water holding capacity [28] in chronosequence overburden manganese mines spoil. There is gradual increase of clay %, water holding capacity, moisture content from degraded fresh overburden mines spoil to an enriched forest soil which contributes soil structural stability and acts as an absorption sink for organic matter [29].

The soil p^H was observed in slight acidic to neutral range from fresh manganese overburden soil (6.73 ± 0.015) to forest soil (7.58 ± 0.052) indicated that there was gradual progress in soil pH towards the neutral range. Analysis of different soil samples shows slightly acidic in fresh manganese overburden spoil (MBO), such types of soil lacks bacterial activity and undergoing process that turn the soil towards sterility[30]. High pH indicates better soil and is often modelled as positive linear relationship with soil quality [23]. The analysis of variance (two way ANOVA) indicated that the variation in pH of the manganese mine spoil with respect to seven different age series in chronosequence was estimated to be statistically significant (p < 0.001).

Wide variation in organic C was exhibited with respect to seven different manganese mine overburden spoil, which showed a range from (0.126 ± 0.001) % to (3.469 ± 0.099)% with minimum in MB0 and maximum in MB10 over time. However, it was evident from the data that higher level of organic C was recorded in the nearby NF soil (3.469 ± 0.099) % as compared to seven different sub-sampling areas of manganese mine overburden spoil across the sites. The current study, indicated the gradual increment in organic C in a successional manner from the nutrient deficient mine overburden spoil to an enriched NF soil across the sites which may be due to initiation of pioneer vegetation and addition of litter from vegetation (31, 32). Several workers reported about the increment in organic C, that exhibits positive correlation with the increase in clay fraction (29,33). Organic carbon estimation acts as an index that represents the productivity in overburden spoil in reclaimed mines and the amount of OC has direct relation with increasing amount of soil organic matter which is contributed by vegetation (34,35), litter fall, root exudation as well as with the age of mine spoil since establishment (36).

The soil organic C, total N and available P in MBO was observed to be substantially low. However, the analysis showed progressive increase in organic C (0.126 % to 3.469 %), total N (0.003% to 0.214%) and available P (0.933

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mg/kg soil to 149.27 mg/kg soil) respectively with minimum in MB0 and maximum in FS. The gradual accumulation of nutrient from MB0 to FS may be attributed to vegetational development and plant species capable of nitrogen fixation, development of mycorrhiza as well as other nutrient immobilizing microbial colonization (34, 35). The variation in clay % and organic C across the sites was positively correlated (r= 0.897, p< 0.001). An increased in clay % and organic matter due to vegetation contributes to development in micropore space from MBO to FS, which ultimately reduces bulk density (37,38). The negative correlation between bulk density and organic carbon (r=-0.913, p<0.01). The relationship between organic carbon and total nitrogen (r = 0.942, p< 0.001) and between organic carbon and available P (r= 0.696,p<0.01) was statistically significant. Significant variation in TN and AP in chronosequence manganese mine overburden spoil over time was revealed by simple correlation analysis (Table 2). Lower available phosphorous in fresh mine spoil (MB0) may be due its acidic nature which inhibits the growth of microbes and amelioration, mineralization and organic matter decomposition [39].

The total nitrogen and available phosphorous in different age series mine spoil exhibited increasing trends over time and have been identified to contribute soil quality in both the managed and natural ecosystems (40,41). Nevertheless, the variation in organic C content in different age series of sub-sampling sites of mine overburden spoil was found to be positively correlated with total N (r = 0.992; p <0.01) and available P (r = 0.835;*p* < 0.01) over time across the sites.

Table 2. Simple correlation coefficients (r) between physico-chemical properties of different age series manganese mine overburden spoil (MBO -MB10) and FS

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
X1	1.00									
X2	-0.993**	1.00								
X3	-0.992**	0.992**	1.00							
X4	0.982**	-0.961**	-0.978**	1.00						
X5	-0.956**	0.951**	0.944**	-0.955**	1.00					
X6	-0.989**	0.985**	0.972**	-0.967**	0.976**	1.00				
X7	-0.969*	0.975**	0.959*	-0.931*	0.969**	0.986**	1.00			
X8	-0.916**	0.910**	0.897**	-0.913**	0.990**	0.954**	0.959*	1.00		
X9	-0.895**	0.896**	0.882**	-0.888**	0.975*	0.942**	0.957*	0.992**	1.00	
X10	-0.561 *	0.576**	0.538*	-0.553*	0.768	0.648*	0.696*	0.835**	0.839*	1.00

** Correlation is significant $p < 0.01$ and * correlation is significant $p < 0.05$.

Xi (i = 1-10) stands for soil sand, slit, clay, bulk density, water holding capacity, moisture content, pH, organic carbon, total nitrogen, available phosphorous.

IV CONCLUSION

All over the aim of eco-rehabilitation programme is to encourage the eco-friendly environment through ecosystem interactions, species diversity and ameliorations in cycling of soil nutrients. Results of the present study suggest that manganese mining sites can be recuperated and transformed into carbon sinks, if felicitous management strategies are adopted. It was clearly indicated from the study that the comprehensive approach based on the combination of quantitative biomarkers established the affixed links between the fluxes propelling nutrient pool, which can be used as recognisable strategy for sustainable soil management. Comparison of the physico-chemical properties of the seven different age series manganese mine overburden spoil divulge the significant annual accumulation of carbon, nitrogen and phosphorous with the gradual improvement of physico-chemical features over time from fresh mine spoil to forest soil. The study suggested that, increment in clay percentage, micropore space, water holding capacity, moisture, and organic matter input, ultimately increases the level of organic C, total N and available P in FS as compare to MB0, that directly influences the soil aggregate formation, structural stability and nutrient retention. The variations in physico-chemical properties influence the microbial community framework in the various age series of manganese mine overburden spoil. Successful reclamation of floristic diversity in manganese mine spoil dump not only impels the natural process of speciation but also became a valuable source of germplasm of various species for future aspects. It improved the environmental conditions by maintaining sustainability in regional areas, including the socio-cultural an economic outlook.

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REFERENCES

[1] Juwarkar AA, Singh L, Kumar GP, Jambhulkar HP, Kanfade H, Jha AK. Biodiversity promotion in restored mine land through plant-animal interaction. J Ecosys Ecograp. 2016 Jan 15;6(176):2..

[2] Haigh MJ. Degradation of 'reclaimed'lands previously disturbed by coal mining in Wales: causes and remedies. Land Degradation & Development. 1992 Oct;3(3):169-80..

[3] Haigh MJ. Soil stewardship on reclaimed coal lands. Land Reconstruction and Management. 2000;1:165-274.

[4] Nicolau Ibarra JM, Moreno de las Heras M. Opencast mining reclamation. In Forest restoration in landscapes: beyond planting trees, Mansourian S, Vallauri D, Dudley N (eds).2005 Springer /WWF: New York, Part D; 370–378

[5] Vangronsveld J, Cunningham SD. Metal-contaminated soils: in situ inactivation and phytorestoration. 1998 Dec.

[6] Eisler R. Arsenic hazards to humans, plants, and animals from gold mining. Reviews of environmental contamination and toxicology. 2004:133-65.

[7] Salomons W. Environmental impact of metals derived from mining activities: processes, predictions, prevention. Journal of Geochemical exploration. 1995 Jan 1;52(1-2):5-23.

[8] Hemida SK, Omar SA, Abdel-Mallek AY. Microbial populations and enzyme activity in soil treated with heavy metals. Water, Air, and Soil Pollution. 1997 Apr;95(1):13-22.

[9] Kandeler E, Tscherko D, Bruce KD, Stemmer M, Hobbs PJ, Bardgett RD, Amelung W. Structure and function of the soil microbial community in microhabitats of a heavy metal polluted soil. Biology and fertility of soils. 2000 Dec;32(5):390-400.

[10] Aronson AF Clewell AF. Ecological restoration: principles, values and structure of an emerging profession. Island Press: Washington, D.C. 2007.

[11] Sobolev D, Begonia M. Effects of heavy metal contamination upon soil microbes: lead-induced changes in general and denitrifying microbial communities as evidenced by molecular markers. International journal of environmental research and public health. 2008 Dec;5(5):450-6.

[12] Forstner U. Land contamination by metals: global scope and magnitude of problem. Metal speciation and contamination of soil. 1995:1-33.

[13] Holtan-Hartwig L, Bechmann M, Høyås TR, Linjordet R, Bakken LR. Heavy metals tolerance of soil denitrifying communities: N2O dynamics. Soil Biology and Biochemistry. 2002 Aug 1;34(8):1181-90.

[14] Sopper WE. Revegetation of a contaminated zinc smelter site. Landscape and Urban Planning. 1989 May 1;17(3):241-50.

[15] Srivastava SC, Jha AK, Singh JS. Changes with time in soil biomass C, N and P of mine spoils in a dry tropical environment. Canadian Journal of Soil Science. 1989 Nov 1;69(4):849-55.

[16] Parkinson D, Gray TR, Williams ST. Methods for study-ing the ecology of soil micro-organisms. Methods for study-ing the ecology of soil micro-organisms.. 1971.

[17] Anderson JM, Ingram JS. Tropical Biology Soil Fertility: A Handbook of Methods. 2nd Edic.1992.

[18] Mishra R. Ecology Work Book Oxford and IBH Publishing Co. New Delhi. 1968.

[19] Jackson ML. Soil Chemical Analysis Englewood Cliffs. NT Prentice Hall Inc. 1958.

[19] Olsen, S.R. and Sommers, L. E.. Phosphorous. In: R.H. Miller and D.R. Keeney. 2nd (eds.). Methods of Soil Analysis, Part- 2. Americal Soc. of Agro., Inc., Madison. 1982.

[20] Varela C, Vazquez C, Gonzalez-Sangregorio MV, Leiros MC, Gil-Sotres F. Chemical and physical properties of opencast lignite minesoils. Soil Science. 1993 Sep 1;156(3):193-204.

[21] Parr JF, Papendick RI. Soil quality: relationships and strategies for sustainable dryland farming systems. Annals of Arid Zone. 1997 Sep 1;36(3):181-91.

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[22] Ezeaku, and Ikemefuna, P. Evaluating the influence of open cast mining ofsolid minerals on soil, land use and livelihood systems in selected areas of Nasarawa State, North-central Nigeria. Journal ofEcology Natural Environment.2012 4(3): 62-70.
[23] Sheoran V, Sheoran AS, Poonia P. Soil reclamation of abandoned mine land by revegetation: a review. International journal of soil, sediment and water. 2010;3(2):13.
[24] Gairola SU, Soni P. Role of soil physical properties in ecological succession of restored mine land-A case study. International journal of environmental sciences. 2010 Oct 1;1(4):475.
[25] Rai AK, Paul B, Singh G. A study on the Bulk density and its effect on the growth of selected grasses in coal mine overburden dumps, Jharkhand, India. International Journal of Environmental Sciences. 2010;1(4):677-84.
[26] Jadoun J, Singh M. A study of physico-chemical properties & heavy metals in contaminated soils of municipal waste dumpsite at Dholpur. International Journal of Sciences. 2014 Jan;3(1).
[27] Alavi I, Alinejad RH, Sadegh Zadeh M. Prioritizing crescive plant species in Choghart iron mine desert region (Used method: Fuzzy AHP). Austral. J. Basic and Appl. Sci. 2011;5:1075-8.
[28] Vengadaramana A, Jashothan PT. Effect of organic fertilizers on the water holding capacity of soil in different terrains of Jaffna peninsula in Sri Lanka. J. Nat. Prod. Plant Resour. 2012 Aug 1;2(4):500-3.
[29] Marshman NA, Marshall KC. Bacterial growth on proteins in the presence of clay minerals. Soil Biology and Biochemistry. 1981 Jan 1;13(2):127-34.
[30] Goswami SH, Das MA, Guru BC. Environmental impact of Siljora opencast manganese mining, Keonjhar: an overview. Vistas Geol Res. 2008;7:121-31.
[31] Fu X, Shao M, Wei X, Horton R. Soil organic carbon and total nitrogen as affected by vegetation types in Northern Loess Plateau of China. Geoderma. 2010 Feb 15;155(1-2):31-5..
[32] Wang B, Liu GB, Xue S, Zhu B. Changes in soil physico-chemical and microbiological properties during natural succession on abandoned farmland in the Loess Plateau. Environmental Earth Sciences. 2011 Mar;62(5):915-25.
[33] Maharana, J.K. and Patel, A.K. Physicochemical characterization and mine soil genes in age series coal mine overburden spoil in chronosequence in a dry tropical environment. Journal of Phylogenetics and Evolutionary Biology,2013a 1(1): 1-7.
[34] Ekka NJ, Behera N. Species composition and diversity of vegetation developing on an age series of coal mine spoil in an open cast coal field in Orissa, India. Tropical Ecology. 2011 May;52(3):337-43.
[35] Kullu B, Behera N. Vegetational succession on different age series sponge iron solid waste dumps with respect to top soil application. Research Journal of Environmental and Earth Sciences. 2011 Jan 5;3(1):38-45.
[36] Seaker EM, Sopper WE. Municipal sludge for minespoil reclamation: I. Effects on microbial populations and activity. American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America; 1988 Oct.
[37] Wong MH. Ecological restoration of mine degraded soils, with emphasis on metal contaminated soils. Chemosphere. 2003 Feb 1;50(6):775-80.
[38] Han F, Hu W, Zheng J, Du F, Zhang X. Estimating soil organic carbon storage and distribution in a catchment of Loess Plateau, China. Geoderma. 2010 Jan 15;154(3-4):261-6.
[39] Noyd RK, Pfleger FL, Russelle MP. Interactions between native prairie grasses and indigenous arbuscular mycorrhizal fungi: implications for reclamation of taconite iron ore tailing. New Phytologist. 1995 Apr;129(4):651-60.
[40] Kucharik CJ, Brye KR, Norman JM, Foley JA, Gower ST, Bundy LG. Measurements and modeling of carbon and nitrogen cycling in agroecosystems of southern Wisconsin: potential for SOC sequestration during the next 50 years. Ecosystems. 2001 Apr;4(3):237-58.
[41] Sheoran, S., Sheoran, V. and Poonia, P. Rehabilitation of mine degraded land by metallophytes. Mining Engineers Journal, 2008,10(3): 11-16.

