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NITRIFICATION RATE IN COAL MINE SPOILS OF KHUDIYA RIVER BASIN

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कोयले के कचरे से मिट्टी की पुन:प्राप्ति की प्रक्रिया बहुत ही धीमी होती है, तथा यह मिट्टी के बायोडाटा एवं पर्यावरणीय कारणों से प्रभावित होती है।

विभिन्न समयों की खनन मिट्टी तथा फार्म/जंगल की मिट्टी के नाइट्रीकरण का तुलनात्मक अध्ययन कोयले के कचरे में विकास की दर की वास्तविक स्थिति को दर्शाता है। इस अध्ययन में कोयले के कचरे की पुन:प्राप्ति की दर को नाइट्रीकरण की दर एवं सामान्य मिट्टी बनने में लगने वाले समय के आधार पर जानने की कोशिश की गई है। नाइट्रीकरण दो जीवाणुओं के क्रिया-कलापों तथा 'sere' की वर्तमान स्थिति पर निर्भर करता है। खुदिया बेसिन में लगभग समरूप भौतिक, भौगोलिक एवं वातावरणीय स्थितियाँ प्रदर्शित करने वाले क्रमश: 0, 5, 10, 16, 20, 24, 30 वर्ष की उम्र के कोयलों के विभिन्न कचरों पर एक अध्ययन आयोजित किया गया, जिसमें 0-30 वर्ष के मिट्टी में पैरामीटरों की सीमा इस प्रकार थी - नमी की मात्रा (4.32-7.18%) जलवहन की क्षमता (26.8-48.6%), ढेर का घनत्व (1.26-1.67 मीटर /से.मी.^{3}), pH (5.4-7.1), विद्युतीय चालकता (0.6-1.02 मीटर म्हो/से.मी.), पोटासियम की मात्रा (206.5-296.2 किलो/हेक्टेयर), फासफोरस (6.7-16.6 किलो ग्राम/हेक्टेयर) तथा ऑरगैनिक कार्बन (3.26-1.46%)।

कोयले के कचरे में विद्यमान नाइट्रेट तथा नाइट्राइड 20 वर्ष तक घटते हैं तथा उसके बाद उसमें वृद्धि होती है, जबकि शुद्ध नाइट्रीकरण की दर में वृद्धि लगातार 30 वर्षों की अवस्था के ग्रेडियेन्ट के अनुसार होती है। नाइट्रीकरण की दर के अनुसार फार्म की जमीन की मिट्टी के समान अनुकूल बनने में कोयले के कचरे को लगभग 24 वर्ष लगते हैं। नाइट्रीकरण वृद्धि की दर 0.545 किलो प्रति हेक्टेयर प्रति वर्ष होती है। यह तथ्य यह प्रमाणित करता है कि खदान की मिट्टी का पी०एच० अम्लीय होता है, और यह माइक्रोबियल खनिजीकरण को प्रमाणित करता है।

INTRODUCTION

The opencast mining activities involve dumping of top soil and semicarbonised sedimentary rocks in the form of coal spoils in large quantity. The disturbed soil has a tendency to regain natural soil quality and coal spoil is not an exception to this. Restoring Nitrogen cycle is one of the major goals of ecosystem recovery in these disturbed environments (Whifeford 1988). The first step in any restoration strategy of course is to protect the disturbed habitats and communities from being further wasted and from loosing the extent genes (Singh & Jha 1993). Restoration success depends on the augmentation 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 and Lindmann 1982. Srivastava et.al 1989).

The bio-available forms of nitrogen are NH_4^+ and NO_3^-. 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. One important non-biological even in the nitrogen cycle is nitrate leaching because of its negative charge. Nitrate is not strongly absorbed 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 because availability of nitrate (one of nutrients) determines 'sere' and vice versa. Again any further evolution in ecosystem is greatly influenced by the availability of nutrients. Once nutrients are transformed, if plant are present to utilize them there is very less possibility to transformed back, the same. However, workers like Coyne, Zhad, Mackown and Burnhisel (1990) gave preference to gross nitrification over net nitrification. Hence comparison of the nitrification rate of changing land with stable ecological state gives a clear picture of exact status of the developing coal spoils. In this paper an attempt has been made to quantify the nitrification rate and formation of available

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nitrogen in the soils of coalmines overburden dumps located in more or less similar geographical and climatic conditions in Dhanbad district.

MATERIALS AND METHODS

The occurrence of coal spoils with different age gradient in a confined area was the virtue for which Khudiya river basin was selected for study zone. Khudiya originates from the Tundi hills and flows more or less parallel to the river Damodar in Nirsa block. Damodar is the ultimate destination of river Khudiya via Baraker River. Khudiya river basin located between latitude 23^{0} 41' to 23^{0} 47' north and longitude 86^{0} 17' to 86^{0} 26' east. Gondwana and Vindhyan spell the geology of the basin. Soil of Khudiya river basin is red and yellow loam sedimentary types. They have a tendency of laterization, are highly leached, neutral and acidic in reaction, deficient in organic matter, nitrogen and available phosphoric acid but potash content is high.

The predominant 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 varies between 105 km/h (maximum) during summer and 10.8 km/h (minimum) during winter. Annual rainfall over the basin varies between 765 - 1607 mm with an average of 1200 mm of which 80% occurs during the monsoon. The evaporation is maximum during summer (21 mm) and minimum monsoon season (2.5 mm). Khudiya river basin represents tropical climate with hot summer and cold winter. The month of 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 temperature fells down below 4 ^{0}C.

The floral biodiversity of the basin is rich and is 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 represent the faunal biodiversity of the basin.

Sample Collection

The soil sampling procedure is based on the recommendation of chemical soil test procedure for the North central region, Bulletin no 499 (revised) October 1980 published by the North Dakota Agricultural experiment station, North Dakota University. Study has been conducted on a series of coal spoil, 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 most was sieved (<2 mm) and divided into three parts. First part in the field moist condition was used for the determination of pH, mineral NO_3^-N 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 air dried and used for the analysis of water holding capacity, bulk density and organic carbon.

Soil Analysis

The moisture content was measured according to IS : 2720 Part II (1973). Bulk density was determined as per IS: 2720 XXIX (1975). Water Holding Capacity was measured by perforated box method. Soil pH was measured according to IS : 2720 part XXVI (1973). The Electrical conductivity was measured as per IS : 2720 Part XXI (1977). Organic carbon was determined using IS : 2720 Part XXII (1972). Phosphorous as Phosphate was measured by orthophosphate method (Handbook of reference methods for soil testing 1980 published by the council on soil testing and plant analysis). Potassium was determined by Ammonium acetate extractable measured by AAS. NO_3^-N was determined with cadmium reduction method (Handbook of reference methods for soil testing 1980 published by the council on soil testing and plant analysis).

Nitrate-mineralization (Nitrification) rate was measured by a buried bag method technique (ENO 1960). A portion of fresh soil sample was incubated in the soil at 10-cm depth using a sealed large polythene bag. Coarse roots and any large fragments and organic debris were removed through sieving in order to avoid any marked immobilization during incubation (Ross et al 1985, Schimel and parton, 1986). NO_3^-N were determined at time zero and after 30 days of field incubation. NO_3^-N was measured by "cadmium reduction method". The increase in NO_3^-N during incubation is referred to as nitrification.

RESULTS

Physical Status of Coal Spoils

The fresh coal spoil have bulk density of about 74% and 75% of wood land and farm land respectively and it increases with the age. Fresh coal spoil, has moisture content of around 54% of woodland and 51% of farmland soil. Where as water holding capacity is approximately 61% and 58% of woodland and farmland respectively. The water holding capacity goes higher as it becomes older and older but the initial water holding capacity is severely low.

Chemical Status of Coal Spoils

The pH of the region varies between 5.4 and 7.1. Conductivity of fresh coal spoil, is about 51% and 57% of woodland and farmland respectively. The potassium content of fresh coal spoil is approximately 62.4% and 68% of woodland and farmland respecting while phosphorus content is around 29% and 32% respectively. The organic carbon value for fresh dump, is about 758% and 652% of woodland and farmland. It is quite clear that coal spoil have very high organic carbon content. NO_3^-N rang is from 1.53 to 3.79 kg/ha in the case of coal spoils while it is around 3.65 and 3.34 kg/ha in case of woodland and farmland respectively.

Nitrification Rate

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

DISCUSSION

Physical Status

Bulk density is inversely related to pore space of soil. Hence, compactness increases with the age in the coal spoil. In the present study there is slightly higher bulk density in farmland and this alteration may be cause by the erosion. That is normal as farm land situated in the bank of reservoir Damodar and erosion always erode the lighter constituent of the soil. There is a negligible effect of increasing bulk density on nitrification (V. Rasiah & B. D. Kay, 1997).

The moisture in soil is not only important as a solvent and transporting agent of nutrients but it maintains texture and compactness of soil and make it habitable for micro-flora, plant and animals. Moisture and temperature are the major edaphic factor controlling the mineralization of carbon and nitrogen (Campbell et. al 1994) soil aeration is dependent on soil moisture and saturated soil tends to be anaerobic. Whereas dry soil are usually aerobic. But soil is a heterogeneous environment. Even saturated soil contains pocket of aerobic regimes and dry soil harbor anaerobic microsytes that exist within the center of secondary agent although the bacteria are the least tolerant of low soil moisture. Water holding capacity of soil depends upon the physical and chemical nature of the soil. Since rainfall is more than sufficient in the region the low water holding capacity of soil cause erosion of organic manure, and it also causes more leaching of the nutrient. When vegetation becomes stable the leaching and erosion becomes low and the water holding capacity become considerable.

Chemical Status

In our study the hydrogen ion concentration is lower at freshly formed coal spoil and it gradually increases towards neutral. It becomes comparable to adjacent grassland at the age of 24. Soil pH is recognized as an important regulator of microbial activity and the composition of microbial population (Paul and Clark, 1996). Adam and Martin (1984) concluded that mineralization of organic nitrogen occurs over the entire pH range but the rate decreases progressively below about 6. That can be one of the root causes of low nitrification rate in the early stages of coal spoil. Dancer et al (1973) showed that nitrification decreases 3 to 5 fold as pH decreases. The unaffected conversion of organic nitrogen to NH_4^+ at low pH leads to an accumulation of NH_4^+ in coal spoils, as it is not leachable due to positive charge. The accumulation of NH_4^+ is the cause of increasing pH of soil along with age.

Biederback et al (1995) demonstrated that even when pH was decreased from 5.2 to 4.3 by a long term use of nitrogen fertilizers, acidity did not reduces population of fungi and bacteria in a loam soil. Undisturbed soil usually have fairy stable pH value within the range of 6-8 and most soil organism have pH optimize within this range hence in term of pH the recovery completed just before 20 year. The nitrification rate is also satisfactory above 20 years of age. However soil organisms are not affected normally by soil pH unless a drastic change occurs.

Coal spoils of this study site having considerable normal conductivity. It indicates the possible existence of Chloride, nitrate, sulfate, phosphate anions and sodium, calcium, magnesium, iron, aluminium cations. As the spoils becomes older the total soluble solid content also becomes fairly good (1.02 m mho/cm) at the 30 years.

Potassium content of the spoil are notably medium in the newly formed coal spoil. As the entire basin has the high potassium content, along with age it becomes high. There may be some impact of potassium content on the nitrification rate as both exhibits similar fashion of increase in the coal spoils. Phosphorous is the another nutrient having considerable presence in coal spoil except 0-5 year. This rapid recovery of phosphorous is an interesting event in the coal spoils. Like potassium it is also shows the similar fashion of increase as nitrification rate.

The extent of NH_4^+N liberation from the organic material is important for the spatial distribution of nitrifying activity and hence for the coupling between nitrification and denitrification. A relatively low and steady NH4+ liberation may lead to an extremely close coupling between nitrification and denitrification (Nielson et al 1996).

Table 1 : Showing the physical attributes / state of coal spoil

PARAMETERS	0-30 YEARS COAL SPOILS Min	Max	Grass/farmland	Woodland	METHODOLOGY
Moisture Content (%)	4.32	7.18	8.36	7.90	IS : 2720 Part II (1973)
Bulk Density (g/cm^3)	1.26	1.67	1.70	1.66	IS : 2720 XXIX (1975)
W.H.C. (%)	26.8	47.5	45.8	43.9	IS : 2720 part XXVI (1973)

Table 2 : Showing Criteria of Total Soluble Solid w.r.t. Conductivity as per Indian norms

Sl. No.	Conductivity (m/bridge reading)	Total Soluble Solid Content
1	<1 m mho/cm	Normal
2	1-2 m mho/cm	Fairly good
3	2-3 m mho/cm	High
4	>3 m mho/cm	Very high

Table 3 : Showing different soil parameters with their relevant Indian norms

Sl. No.	Parameters	Unit	Low	Medium	High
1	Organic carbon	%	<0.5	0.5-0.75	>0.75
2	Available Nitrogen	Kg/ha	<280	280-560	>560
3	Available Phosphorous	Kg/ha	<10	10-25	>25
4	Available Potassium	Kg/ha	<110	110-280	>280

Table 4 : Showing the chemical attributes / state of coal spoil

PARAMETERS	0-30 YEARS COAL SPOILS Min	Max	Grass/farmland	Woodland	METHODOLOGY
pH	5.4	7.1	6.8	6.3	IS : 2720 Part XXVI (1973)
Salinity/Conductivity (m mho . cm^{-1})	0.66	1.02	1.15	1.28	IS : 2720 XXI (1977)
Potassium (Kg./ha)	206.5	296.2	303.0	329.6	*
Po_4-P (Kg./ha)	6.7	18.6	20.4	22.6	**
Organic Carbon (%)	1.13	3.26	0.05	0.43	IS : 2720 Part XXI (1977)
NO_3-N (Kg./ha)	1.53	3.79	3.34	3.65	***
Nitrification Rate (Kg./ha./yr.)	15.37	31.72	27.14	38.10	****

* *determined by Ammonium acetate extractable measure by AAS*

** *orthophosphate method CSTPA 1980*

*** *No_3-N was determined with cadmium reduction method CSTPA 1980*

**** *Nitrate mineralization (Nitrification) rate was measured by a buried bag method technique (ENO 1960)*

Investigation by Wetselaar et al, (1972) indicated inhibitory effects of nitrifying activity by NH_4^+ poisoning. Concentration above 200 mm and NH_4^+ poisoning may thus lead to reduced rate of coupled nitrification and denitrification. The decreasing trend of organic carbon supports the nitrogen availability to the plant. Because increasing carbon availability in soil leads to a decrease in nitrogen availability for the plant through the immobilization of nitrogen in microbial biomass and to an increase in the temporal heterogeneity of soil property (Antanio Gallardo and Jose Merino 1997). This is why the nitrification and vegetation are restricted in the early stages of coal spoil. Since nitrogen cycle is linked to the carbon cycle (McGill et al 1981) hence disappearance of organic carbon must supports the nitrification in coal spoils.

Comparatively good amount of available nitrate as nitrogen and low nitrification rate in 0-5 year coal spoil indicates the lower microbial activity at the early stage. The low immobilization and higher transformation of organic nitrogen into inorganic form and no vegetation to take-up the available nitrate may result in accumulation of higher nitrate as nitrogen in the soil.

Previously present or recently formed NO_3-N in the sub soil may also move up and accumulate in the top soil (Sanchez, 1976) this facts also reflected from the minimum level of nitrate in 20 year coal spoil having comparable good rate 26.32kg/ha/yr. of nitrification.

This study was carried out in those month (November - March) when nitrification is medium which marks the average rate and more near to the original condition of coal spoil as indicated by Singh, Raghuvanshi, and Singh (1990). The nitrification rate in the 24 and 30 year coal spoils 27.63 and 31.72 kg/ha/yr. respectively. While farmland rate indicated 27.14 kg/ha/yr. Therefore it can be XX concluded that coal spoil wills take approximately 24 years to reach the adjacent farmland and grassland.

CONCLUSION

As far as the quantification of net nitrification rate is concerned the coal spoil may take 24 year to recover it self as the farmland / grassland ecosystem. Further study is needed for the quantification of time required to reclaim coal spoils as forest ecosystem. The fact goes in the favour 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 colonization of vegetation on the spoil. Direct seeding for revegetation of coal spoil may be favoured because this is easier and cost effective then planting but proper aftercare is essential plants with nodule and mycorrhizal association allowed both increased phosphorous up take and nitrogen fixation.

The primary approach of ecosystem to restoration of coal spoil is 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 restoration in coal spoil may be partially solved by a step wise time bound restructuring of vegetation and manipulation of nutrient cycling rate by sustainable resource use.

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