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RESEARCH ARTICLE

Soil and vegetation characteristics associated with mine overburdens of an opencast coalmine area of Burdwan district, West Bengal, India

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Abstract

Soil properties and floristic composition of the overburdens were studied in Ramnagore opencast colliery, Raniganj, West Bengal. Soil characteristics such as pH, specific conductance, concentrations of nitrogen, organic carbon and phosphate showed a gradual increase in age series of overburdens. A total of 64 plant species (59-dicots and 4-monocots) were recorded, out of which 49 were r-strategists and 15 were K-strategists. According to biological spectrum data, plant species were distributed into 14 phanerophytes, 6 chamaephytes, 5 hemicryptophytes and 39 therophytes, and when compared with the Raunkiaer’s normal spectrum revealed to be thero-chamaephytic in nature, thus indicating aridity. Overall both the soil and vegetation properties clearly indicated the occurrence of natural succession process.

INTRODUCTION

Coal mining especially of opencast type results in derangement of landscape pattern and destruction of overlying vegetation. During excavation, huge overburden dumps and voids are formed (Namdeo, 1989). Soil of these dumps is the mixture of coal particle and rocky substances and generally known as mine spoils (Mitchell, 1959). The spoil shows adverse effect on the growth of vegetation due to low organic carbon content, unfavorable pH, oxygen deficiency (Agarwal *et al.*, 1993) and low water holding capacity (Vogel, 1982) along with inadequate nutrient conditions (Jha and Singh, 1991).

In spite of such stress factors and other environmental constraints, the plant communities were not only thriving in the mine overburdens but also proceeding towards the attainment of stability through natural succession (Das *et al.*, 2013; Biswas *et al.*, 2013; Roy *et al.*, 2014 a, b), however it is extremely lengthy process (Dobson *et al.*, 1997). In order to optimize conditions for fast and successful revegetation through suitable amendment it is necessary to understand the status of the damaged site in view of spoil characteristics and vegetation (Reddy and Reddy, 2001; Sheoran *et al.*, 2010).

In view of this, the present work was undertaken on the different points of Ramnagore opencast coalmine area, Burdwan district, West Bengal, India. The primary objective of the present work is thus assessment of some physicochemical properties of the overburdens in age series and stocktaking as well as determination of biological spectrum of the floristic diversity on the study site so that the findings may prove useful in formulating strategies for augmenting the process of revegetation and eventual restoration.

MATERIALS AND METHODS

Study site

The present study was carried out in Ramnagore opencast colliery (Figure 1) which is located within 23°45.230´ N Latitude and from 86°50.133´ E Longitude covering an area of 6.56 sq km in the western part of the Raniganj coalfield in Burdwan district, West Bengal. Five overburden dumps of different ages viz., 3 yr (OB_3), 9 yr (OB_9), 14 yr (OB_{14}), 19 yr (OB_{19}) and 40 yr (OB_{40}) were selected as data points within the study site.

Sampling and Analyses

Field work was performed during March 2013-14 in five overburden dumps resulting from opencast coal mining in Ramnagore colliery. Spoil sample from each of the mine overburdens was collected randomly from 0-10 cm soil depth, by digging pits of (10x10x10) cm^3 size. These samples were analyzed for various characteristics such as pH, specific conductance, concentrations of nitrogen, organic carbon and phosphate (Brady, 1920). Similarly, plant specimens were collected for identification with the help of standard taxonomic literature (Prain, 1903) and authentic specimens kept in the herbarium of Burdwan University (BURD). The plant species thus recorded were also classified into different lifeforms for revealing the phytoclimate (Raunkiaer, 1934) and r- and K- strategists.

RESULTS AND DISCUSSION

Characteristics of the spoil samples such as pH, specific conductance, concentrations of nitrogen, organic carbon and phosphate (OB_3–OB_{40}) have been presented in Table 1. The analysis indicated that pH of OB_3 was acidic and then there was an increase in pH conditions with the age of spoils. Gradual improvement in the pH values was due to accumulation of basic cations (Rai *et al*, 2011). Specific conductance was found to follow a decreasing pattern from 26.97 mmho/cm to 12.78 mmho/cm in selected OBs of the study site. The higher values were due to upward migration of different salts with partially combustion of coal particles. The lower values were due to presence of lower amount of salts in the aged overburden samples.

Organic carbon content was found to be more or less along an increasing gradient, the values ranged from 0.23% (OB_3) to 2.85% (OB_{40}). Similar trend was noticed in case of total nitrogen content (with 0.23 ppm in OB_3 to 12.78 ppm in OB_{40}) and phosphate content (varied from 3.94 ppm in OB_3 to 14.2 ppm in OB_{40}). These data were in accordance with the findings of Sheoran *et al*. (2008) and Rai *et al*. (2011). Deposition of organic carbon was due to litter accumulation and subsequent decomposition by soil microbes. Increase in total nitrogen content in older OBs could be due to presence of leguminous plants associated with nitrogen fixing microbes (Maiti *et al*., 2002). Gradual improvement of phosphate content with age of OBs was due to increased rate of mineralization and organic matter decomposition (Sheoran *et al*., 2010).

As many as 64 plant species were recorded from all the respective overburdens as a whole, out of which 59 and 4 were dicots and monocots respectively. The species were distributed into 39 families and 57 genera. Among these species 30 were herbs, 11 shrubs, 11 climbers, 3 creepers and 9 trees (Table 2). Though most of the species were herbaceous, establishment of other types including trees indicated the successional trend.

Further analysis showed that 49 species were r-strategists while 15 were K-strategists (Table 2). Greater proportion of r-strategists (i.e., the herbs and climbers, utilizing most of their primary production towards reproduction) is indicative of an uncertain and poorly stabilized community. However, they take part as the initial colonizers in the process of natural succession (MacArthur and Wilson, 1963).

In this study, the life-forms of 64 species were determined following Raunkiaer's system of classification (1934) and the biological spectrum was obtained subsequently. The data revealed 14 phanerophytes, 6 chamaephytes, 5 hemicryptophytes and 39 therophytes to be existing in the study site (Table 3). Interestingly representative genera belonging to cryptophytes could not be identified. When biospectrum data was compared with Raunkiaer's normal spectrum revealed much lower abundance of phanerophytes and hemicrytophytes while higher abundance of therophytes (Figure 2), thus indicating aridity (Roy and Mukherjee, 2011). According to the data, the micro-climate was thero-chamaephytic in nature. Both therophytes and chamaephytes play important role in retention of soils, nutrients and water.

Table 1: Properties of mine spoil samples collected from different age series overburdens

Parameter	**OB_3**	**OB_9**	**OB_{14}**	**OB_{19}**	**OB_{40}**
pH	6.1	6.5	7.2	7.1	7.4
Specific conductance (mmho/cm)	26.97	20.85	19.69	18.89	12.78
Organic Carbon (%)	0.23	0.37	0.76	1.1	2.85
Nitrogen (ppm)	0.23	2.13	5.56	8.48	12.78
Phosphate (ppm)	3.94	6.1	9.8	11.92	14.2

Table 2: An account of the flora and its various characteristics observed in the study site

Name of the plant	Family	Habit	Life- form Category	Strategy (r/K)
1. *Albizia lebbeck*	Mimosaceae	Tree	Phanerophyte	K
2. *Alstonia scholaris*	Apocynaceae	Tree	Phanerophyte	K
3. *Arva lanata*	Amarantheceae	Herb	Therophyte	r
4. *Andrographis paniculata*	Acanthaceae	Herb	Therophyte	r
5. *Andrographis echoides*	Acanthaceae	Herb	Therophyte	r
6. *Annona squamosa*	Annonaceae	Shrub	Phanerophyte	K
7. *Azadirachta indica*	Meliaceae	Tree	Phanerophyte	K
8. *Bauhinia purpurea*	Caesalpiniaceae	Shrub	Phanerophyte	K
9. *Boerhavia diffusa*	Nyctaginaceae	Herb	Therophyte	r
10. *Bryonia laciniata*	Cucurbitaceae	Climber	Therophyte	r
11. *Butea monosperma*	Fabaceae	Tree	Phanerophyte	K
12. *Calotropis gigantea*	Asclepiadaceae	Tree	Phanerophyte	K
13. *Cardiospermum helicacabum*	Sapindaceae	Climber	Therophyte	r
14. *Cassia siamea*	Caesalpiniaceae	Tree	Phanerophyte	K
15. *Cassia tora*	Caesalpiniaceae	Herb	Therophyte	r
16. *Cayratia pedata*	Vitaceae	Climber	Therophyte	r
17. *Cayratia reticulata*	Vitaceae	Climber	Therophyte	r
18. *Centrantherum anthelminticum*	Asteraceae	Herb	Therophyte	r
19. *Citrus limon*	Rutaceae	Shrub	Phanerophyte	K
20. *Cleodendrum viscosum*	Verbenaceae	Herb	Hemicryptophyte	r
21. *Coccinia grandis*	Cucurbitaceae	Climber	Therophyte	r
22. *Combretrum roxburghii*	Combretaceae	Climber	Hemicryptophyte	r
23. *Commelina benghalensis*	Commellinaceae	Herb	Hemicryptophyte	r
24. *Corchorus acutangulus*	Tiliaceae	Herb	Therophyte	r
25. *Crotolaria pallida*	Fabaceae	Herb	Therophyte	r
26. *Croton bonplandianum*	Euphorbiaceae	Herb	Therophyte	r
27. *Dalbergia sissoo*	Fabaceae	Tree	Phanerophyte	K
28. *Desmodium triflorum*	Fabaceae	Creeper	Therophyte	r
29. *Dioscorea alata*	Dioscoreaceae	Shrub	Phanerophyte	r
30. *Eupatorium odorata*	Asteraceae	Herb	Therophyte	r
31. *Evolvulus nummularius*	Convolvulaceae	Creeper	Hemicryptophyte	r
32. *Ficus hispida*	Moraceae	Shrub	Chaemaephyte	K
33. *Heliotropium indicum*	Boraginaceae	Herb	Therophyte	r
34. *Heliotropium supinum*	Boraginaceae	Herb	Therophyte	r
35. *Kyllinga monocephala*	Cyperaceae	Herb	Therophyte	r
36. *Lantana camara*	Verbenaceae	Shrub	Therophyte	r
37. *Leucas aspera*	Lamiaceae	Herb	Therophyte	r
38. *Mikania micrantha*	Asteraceae	Climber	Therophyte	r
39. *Murraya koenigii*	Rutaceae	Shrub	Chamaephyte	r
40. *Olax scandens*	Olacaceae	Climber	Hemicryptophyte	r
41. *Oldenlandia corymbosa*	Rubiaceae	Creeper	Therophyte	r
42. *Oplismenus compositus*	Poaceae	Herb	Therophyte	r
43. *Parthenium hysterophorus*	Asteraceae	Herb	Therophyte	r
44. *Pennisetum pedicellatum*	Poaceae	Herb	Therophyte	r
45. *Phyla nodiflora*	Verbenaceae	Herb	Therophyte	r
46. *Piper longum*	Piperceae	Climber	Therophyte	r
47. *Polygonum barbatum*	Polygonaceae	Herb	Therophyte	r
48. *Polygonum plebium*	Polygonaceae	Herb	Therophyte	r

49. Ruellia prostrata	Acanthaceae	Herb	Therophyte	r
50. Saccharum spontaneum	Poaceae	Herb	Therophyte	r
51. Sesbania grandiflora	Fabaceae	Shrub	Chaemaephyte	r
52. Sida acuta	Malvaceae	Herb	Therophyte	r
53. Solanum indicum	Solanaceae	Herb	Therophyte	r
54. Solanum sysimbrifolium	Solanaceae	Shrub	Chamaephyte	r
55. Spermacocci hispida	Rubiaceae	Herb	Therophyte	r
56. Stephania japonica	Menispermaceae	Climber	Therophyte	r
57. Syzygium cumini	Myrtaceae	Tree	Phanerophyte	K
58. Tamarindus indica	Fabaceae	Tree	Phanerophyte	K
59. Trichosanthes cucumererina	Cucurbitaceae	Climber	Therophyte	r
60. Tridax procumbens	Asteraceae	Herb	Therophyte	r
61. Vernonia cinaerea	Asteraceae	Herb	Therophyte	r
62. Xanthium indicum	Asteraceae	Herb	Therophyte	r
63. Ziziphus mauritiana	Rhamnaceae	Shrub	Chaemaephyte	K
64. Ziziphus oenoplea	Rhamnaceae	Shrub	Chaemaephyte	K

Table 3: Biological spectrum of the study site

Life forms	**Raunkiaer's standard**	**No. of Species**	**Obtained biological spectrum**
Phanerophytes	46	14	22
Chamaephytes	9	6	9
Hemicryptophytes	26	5	8
Therophytes	13	39	61
Cryptophytes	6	0	0

Figure 1: Study site and its location in Burdwan District in West Bengal, India. A) map view of West Bengal state in green colour, B) map view of Burdwan district in red colour within West Bengal, C) detailed map view of the study site, and D) a glimpse of the study site.

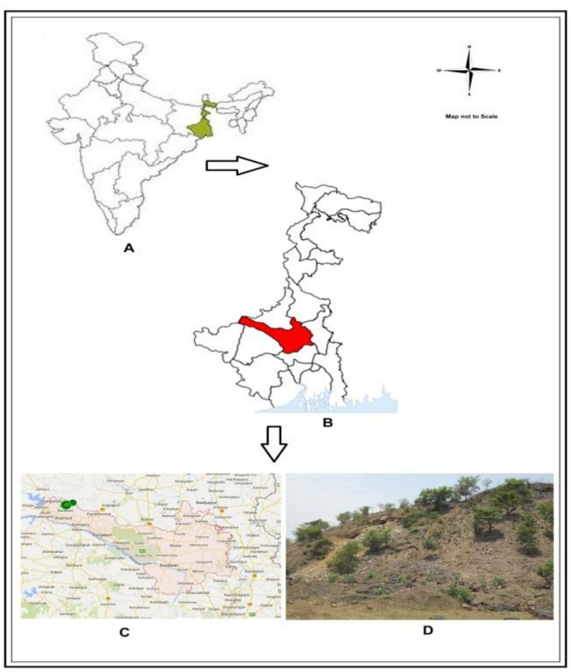
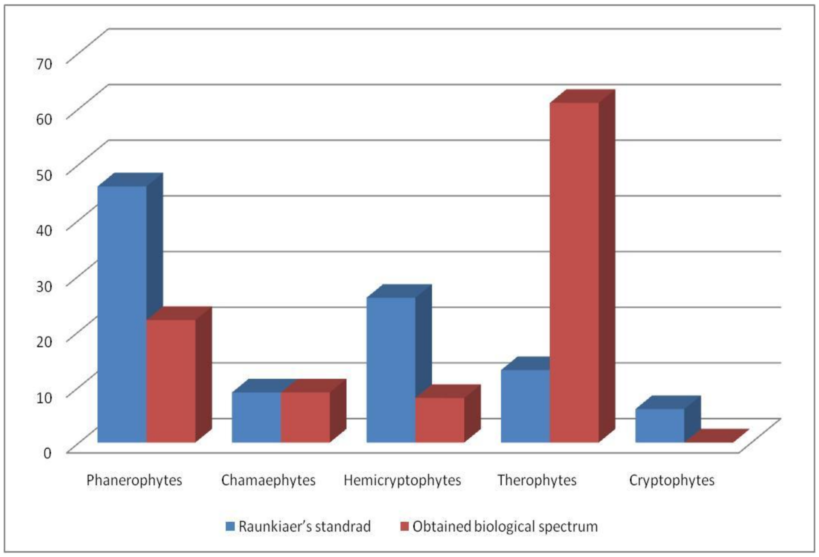


Figure 2: Comparison of the Biological Spectrum of Ramnagore colliery with Raunkiaer's Normal Spectrum



CONCLUSION

The mining activities degrade the original landscape by the formation of mine overburden leading to alterations in geochemical cycles, disruption of ecosystem stability and function. In context of the present study it can be said that with increase in age of overburdens, gradual improvement of physico-chemical properties are observed that are important factors for establishment of vegetation. On the other hand, the current vegetation pattern in the study site clearly reflected the occurrence of natural succession. This fundamental study provides understanding of the natural succession process and is useful for optimizing reclamation strategies.

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