Plants and air pollution: the possible role of plant in air pollution management

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1. Introduction

Plants are the best tools for the study of various climatic and environmental changes (Falla et al., 2000; Grant, 1998). Phytodiversity of a community is affected in response of various pollutants (Van Geoenendael et al., 2000). In other words, we can say that industrial air pollutants affect the phytosociology and biodiversity of an area. Various researchers have done such study in responses to varied polluted environments such as Rosenberg (1979) for coal-burning power plant; Darley (1966) for cement industry, and Tripathi et al. (1999) in response to automobile exhaust. Every plant community is characterized by its species diversity (Krebs, 1985) and it can be studied in detail by considering a number of parameter such as frequency, density and dominance. The relative study of these characters with respect to different plants along with the Importance Value Index (IVI) reflects the complete image of the community of an area (Odum, 1971; 1983; Whittekar, 1975). To this end, phytosociological surveys of different communities have also been conducted (Somak et al., 2000; D'Altero, 2000; Webb and Vermatt, 1990; Chen et al., 2000).

The effectiveness of plants in intercepting and retaining atmospheric pollutants depends on several factors, viz. shape, size, moisture level, surface texture and nature (soluble or insoluble) of both the particulate matter and gas and the intercepting plant parts (Ingold,1971). Air pollutants in urban and industrial areas may be adsorbed, absorbed, accumulated or integrated into the plant body and, if toxic, may injure them to some degree. The level of injury will be high in sensitive species and low in tolerant ones. Sensitive species are useful as early warning indicators of pollution, and the tolerant ones help in reducing the overall pollution load, leaving the air relatively free of pollutants (Rao, 1983). Plants act as a sink and as living filters to minimize air pollution by absorption, adsorption, detoxification, accumulation and/or metabolization thus improving air quality by providing oxygen to the atmosphere (Hill, 1971; Bennett and Hill, 1975; Smith and Dochinger, 1976; Beckett et al., 1998; Pandey et al., 2005).

Coal has emerged as principle source of energy with 60 % contribution in energy consumption, and playing a pivotal role in shaping the profile of the national economic development of India. Open cast coal mining (OCM) dominates coal production in India (70 % of total production) due to ease of extraction. However, over-exploitation of coal is causing degradation of the environment especially the air. Present work deals with study of plants in relation to air pollutants in open cast coal mine area which was carried out in Bina open cast project, one of the biggest coalmines of Northern Coalfields Limited (NCL), India. To this end, five study sites were selected for detailed investigation based on micrometeorological parameters and nature of mining activities including one control site. Ambient air quality monitoring and phytosociological studies of plant species were performed at each study site. In addition, Air Pollution Tolerance Index (APTI) and Anticipated Performance Index (API) of plants were calculated by analyzing some biochemical parameters and considering some socioeconomic and biological properties of plants. Finally, the plant species with high APTI and API were recommended for the green belt development and long-term air pollution management in the open cast coal mine area.

2. Method

2.1. Phytosociology (Study of relative frequency, density, and dominance of plants: Importance Value Index calculation)

In any community structure, the quantitative value of each of the frequency, density and dominance has its own importance, but the total picture of ecological importance cannot be obtained by any of these. Therefore, in order to have an overall of ecological importance of a species with respect to the community structure, the value of relative frequency, relative density, and relative dominance were added together, this value was out of 300 and is called importance value index or (IVI) of the species.

$$\text{R.F. of a species} = \frac{\text{Number of occurrence of a species}}{\text{Number of occurrence of all species}} \times 100 \quad \cdots\cdots \quad (1)$$

$$\text{R.D. of a species} = \frac{\text{Number of individuals of the species in all quadrats}}{\text{Number of individuals of all the species in all quadrats}} \times 100 \quad \cdots\cdots \quad (2)$$

$$\text{R.Do. of a species} = \frac{\text{Total basal area of the species in all the quadrats}}{\text{Total basal area of all the species in all the quadrats}} \times 100 \quad \cdots\cdots \quad (3)$$

$$\text{IVI} = \text{R.F.} + \text{R.D.} + \text{R.Do} \quad \cdots\cdots \quad (4)$$

Where R.F. = Relative frequency, R.D. = relative dominance, and R.Do. = relative dominance.

2.2. Air pollution tolerance and anticipated performance indices

During present investigation, biochemical parameters of plant leaves (i.e., pH, ascorbic acid, total chlorophyll, and relative content of water) were analyzed. Then, APTI was calculated based on following formula (Singh and Rao, 1983).

$$\text{APTI} = A\ (T + P) + R/10$$

Where, A = ascorbic acid content in mg/g of fresh weight, T = total chlorophyll in mg/g of fresh weight P= pH of leaf extract and R= Percent Relative content of water. Assessment pattern for calculation of API is summarized in stepwise manner in Table 1 and 2.

Table 1. Gradation of plant species based on Air pollution tolerance index (APTI) and other biological and socioeconomic characters

Grading Character		Pattern of assessment	Grade allotted
(a)Tolerance	APTI	9.0-12.0	+
		12.1-15.0	++
		15.1-18.0	+++
		18.1-21.0	++++
		21.1-24.0	+++++
(b)Biological and socioeconomic	Plant habit	Small	-
		Medium	+
		large	++
	Canopy structure	Sparse/Irregular/globular	-
		Spreading crown/ open/ semi-dense	+
		Spreading dense	++
	Type of plant	Deciduous	-
		Evergreen	+
Laminar structure	Size	Small	-
		Medium	+
		Large	++
	Texture	Smooth	-
		Coriaceous	+
	Hardiness	Delineate	-
		Hardy	+
	Economic value	Less than three uses	-
		Three or four uses	+
		Five or more uses	++

Table 2. Method for generation of anticipated performance index (API) of plants

Grade	Score (%)	Assessment category
0	Up to 30	Not recommended
1	31-40	Very Poor
2	41-50	Poor
3	51-60	Moderate
4	61-70	Good
5	71-80	Very Good
6	81-90	Excellent
7	91-100	Best

3. Results and observation

3.1. Phytosociology

Table 3. Performance of plant species at various study sites

Sites	Dominant wild plant species having higher IVI		Total no. of plant species	Plant found at control site but not at others
	Name of the plant	IVI		
Jawahar Colony (Site 1)	*Cynodon dactylon* (L.) Pers. *Parthenium hysterophorus* L. *Lantana camara* L. *Saccharum spontaneum* L. *Tridax procumbens* L. *Sterculia villosa* Roxb. ex. Smith in Rees. *Sterculia urens* Roxb. *Desmodium triflorum* (Linn.) DC. *Sida cordifolia* L.	22.29 14.15 13.54 11.85 10.88 9.92 9.56 8.95 8.89	47	*Helicteres isora* L. *Aerva lantana* L. *Aerva sanguinolenta* L. *Cleome viscosa* L. *Calotropis gigantea* R.Br. *Martynia diandra* Glox. *Solanum virginianum* L. *Jatropha gossypifolia* L. *Scoparia dulcis* L. *Sterculia urens* L.
Coal handling plant (Site 2)	*Cynodon dactylon* (L.) Pers. *Lantana camara* L. *Saccharum spontaneum* L. *Parthenium hysterophorus* L. *Desmodium triflorum* (Linn.) DC. *Cassia tora* Linn. *Euphorbia hirta* L. *Jatropha curcus* L. *Ocimum basilicum* L. *Convolvulus arvensis* L.	26.59 20.22 17.48 17.37 16.15 15.35 14.53 14.17 11.37 10.54	29	*Helicteres isora* L. *Achyranthus aspera* L. *Aerva lantana* L. *Boerhaavia diffusa* L. *Cleome viscosa* L. *Curculigo orchioides* Gaertn. *Eclipta alba* L. *Jatropha gossypifolia*_L. *Ocimum sanctum* L. *Sida cordifolia* L.
Near VTC building (Site 3)	*Cynodon dactylon* (L.) Pers. *Lantana camara* L. *Desmodium triflorum* (Linn.) DC. *Euphorbia hirta* L. *Cassia tora* Linn. *Saccharum spontaneum* L. *Ocimum basilicum* L. *Jatropha gossypifolia* L. *Convolvulus arvensis* L.	24.85 18.34 14.87 13.48 13.07 12.00 11.24 10.63 10.12	33	*Helicteres isora* L. *Desmodium triflorum* (Linn.) DC. *Alternanthera sessilis* (L.) DC. *Cleome viscose* L. *Aerva sanguinolenta* L. *Curculigo orchioides* Gaertn. *Eclipta alba* L. *Ocimum sanctum* L. *Jatropha curcus* L.
Near main sub station (Site 4)	*Cynodon dactylon* (L.) Pers. *Parthenium hysterophorus* L. *Lantana camara* L. *Euphorbia hirta* L. *Saccharum spontaneum* L. *Ocimum basilicum* L. *Jatropha curcus* L. *Convolvulus arvensis* L. *Sida cordifolia* L. *Sterculia urens* L.	23.03 16.23 12.99 12.96 11.67 10.85 10.20 9.77 7.79 7.19	37	*Sterculia villosa* *Desmodium triflorum* (Linn.) DC. *Ocimum sanctum* L. *Croton bonplandianum* *Ricinus communis* *Aerva lantana* *Cleome viscosa* *Curculigo orchioides* *Jatropha gossypholia* *Boerhaavia diffusa*
Gharasari village (Site 5)	*Cynodon dactylon* (L.) Pers. *Saccharum spontaneum* L. *Lantana camara* L. *Convolvulus arvensis* L. *Parthenium hysterophorus* L. *Sterculia urens* L. *Tridax procumbens* L. *Evolvulus alsinoides* L. *Desmodium triflorum* (Linn.) DC. *Sterculia villosa* Roxb. ex. Smith in Rees.	18.66 12.45 11.43 8.70 8.452 8.25 8.21 7.73 7.09 6.94	70	

Based on phytosocioligical studies, it was evident that the plants highly sensitive to air pollution were nearly absent at polluted sites. On the other hand, plants found at these sites were less sensitive or somewhat resistant to the air pollution. Moreover, if the sensitive plant species were found, they showed very low value of IVI. This clearly indicated the impact of air pollutants released from mining operations on the species composition and biodiversity. As a general trend, the resistant plants had higher value of IVI near all the polluted sites. At site 5 (Gharasari village), which is control one and far from mining activities plants did not showed any significant correlation among their IVI values and sensitivities.

3.2. APTI and API

Table 4. Anticipated performance of tree species in Bina open cast coalmine area

Plant species	**Grade**		**API value**	Assessment
	Total plus	Percentage		
Ficus infectoria L.	15	88.2	6	Excellent
Ficus religiosa L.	14	82.3	6	Excellent
Mangifera indica L.	14	82.3	6	Excellent
Ficus benghalensis L.	13	76.46	5	Very Good
Dalbergia sissoo Roxb.	12	70.58	5	Very Good
Azadirachta indica A.Juss.	11	64.7	4	Good
Putranjiva roxburghii Wall.	11	64.7	4	Good
Butea monosperma (Lamk.) Taub.	11	64.7	4	Good
Adina cardifolia Hook.f.	11	64.7	4	Good
Psidium guajava L.	11	64.7	4	Good
Syzygium cumini (L.) Skeels.	9	52.94	3	Moderate
Semecarpus anacardium Linn.f.	9	52.94	3	Moderate
Tectona grandis L.	9	52.94	3	Moderate
Zizyphus mauritiana Lamk.	9	52.94	3	Moderate
Zizyphus oenoplia Mill.	8	47.05	2	Poor
Artocarpus lakoocha Roxb.	8	47.05	2	Poor
Terminalia catappa L.	8	47.05	2	Poor
Madhuca indica Gmelin.	8	47.05	2	Poor
Cassia fistula L.	7	41.18	2	Poor
Diospyros melanoxylon Roxb.	7	41.18	2	Poor
Acacia catetchu Willd.	6	35.29	1	Very Poor
Dendrocalamus strictus (Roxb.)Nees.	6	35.29	1	Very Poor
Terminalia bellirica Roxb.	6	35.29	1	Very Poor
Grewia asiatica L.	5	29.41	0	Not Recommended
Acacia ferruginea DC.	6	35.29	1	Very Poor
Bridelia squamosa (Lam.) Gehrm.	4	23.59	0	Not Recommended
Pithocellobium dulce Benth.	4	23.59	0	Not Recommended
Schleichera oleosa (Lour.) Oken.	5	29.41	0	Not Recommended
Nerium odorum Sonnad.	5	29.41	0	Not Recommended

As shown in Table 4, *Ficus infectoria, Mangifera indica* L.and *Ficus religiosa* were judged as excellent performers. F*icus benghalensis* L.and *Dalbergia sissoo* Roxb. were designated very good performers. *Azadirachta indica* A.Juss. and *Putranjiva roxburghii* Wall. were anticipated being good performers. *Psidium guajava* L., *Syzygium cumini* (L.) Skeels., *Semecarpus anacardium* Linn.f., *Tectona grandis* L., *Zizyphus mauritiana* Lamk. and *Madhuca indica* Gmelin. were predicted for moderate performance. Six plant species were recognized as poor performers. Rest of the plant species either were in very poor performers or under not recommended for plantation category. *Ficus infectoria* L., ranks first among all the plants and is a keystone species. Therefore, this will be an ideal species for plantation in the area to maintain the natural ecosystem. Pandey et al., 2005 showed that this tree is also capable of removing vehicle-derived particulates due to magnetic properties. Seeing as Particulate Matter (PM) is the foremost problem for opencast coalmines, this plant is expected to perform well.

One another plant *Mangifera indica* L. was judged as excellent performer. It has a dense canopy of evergreen like foliage. It is well known for its economic and aesthetic value and it may be recommended for planting as a first curtain of the mining areas. *Ficus religiosa* L. was judged in the excellent category and recommended for plantation in mining area. *Ficus benghalensis* L. and *Dalbergia sissoo* Roxb. were designated very good performers. *Azadirachta indica* A. Juss., *Putranjiva roxburghii* Wall., *Psidium guajava* L., *Butea monosperma* (Lamk.) Taub.and *Adina cardifolia* Hook. f. were anticipated to be good performers. Beside these ten good performing species, four tree species were under moderate category and may be recommended for plantation due to their aesthetic value. Conversely, rests of the species naturally growing in the area were either very poor or not recommended for plantation due to their very low value of API.

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