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# QUANTITATIVE EVALUATION OF NATURALLY COLONIZED PLANT SPECIES ON FLY ASH DEPOSIT FOR SUSTAINABLE PHYTORESTORATION

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**ABSTRACT**

Fly ash is the major waste products of industrial plants that pose serious environmental hazards. Proliferation of fly ash deposits and its toxicity have become a global concern, which contaminate the ecosystems of our Earth. The present work was undertaken to study the Phytodiversity of potential plant species that naturally grow on fly ash deposits and quantitatively evaluate their sustainable phytorestoration potentiality. An intensive survey of vegetation was conducted during 2014-2015 in fly ash deposit of NALCO, Koraput, India. In this study 30 plant species were identified which are distributed in 28 genera belonging to 14 different families. Most of the plant species observed belonged to family Asteraceae followed by Poaceae and Fabaceae and 7 species are shrubs and 23 species are herbs. The plant species having phytorestoration potentiality in fly ash deposits were identified on the basis of their frequency, density, dominance and important value index at the study sites. From the study it is evident that species like *Ageratum conyzoides, Alternanthera sessilis, Mimosa pudica, Perotis indica, Blumea lacera, Aristida setacea, Calotropis gigantea, Centella asiatica,* and *Crotalaria striata* are potential plant species having fly ash deposits' restoration potentiality. Furthermore, the naturally colonized species can be used for the phyto-restoration during a re-vegetation plan of new fly ash deposits. This may be used as an easiest, cost-effective and eco-friendly means of phytorestoration.

**Keywords:** Fly ash; IVI; Phytodiversity; Phytorestoration.

## INTRODUCTION

Fly ash is a waste product of Industrial plants that pose serious environmental threat and proliferation of fly ash deposits and its toxicity have become a global concern [1]. In this regard, identification of potential plant species for fly ash deposits' restoration is the main concern. In India, fly ash generation is expected to be 300-400 million tons per annum by 2016-2017 [2]. Fly-ash is a potential source of many macro- and micro elements to plants, including many toxic metals [3]. The most obvious impact to biodiversity from fly ash is the removal of vegetation, which in turn alters the availability of food and shelter for wildlife. At a broader scale, fly ash may impact biodiversity by changing species composition and structure and also exert significant harsh impacts on the surrounding aerial, aquatic and terrestrial ecosystems [4]. Several human health-associated problems have been reported due to fly ash like lung disease, skin disease, eye irritation etc. [4]. As a consequence, the man-made fly ash deposits are recognized as serious hazardous sites on the Earth [5]. So far, the biostabilization of fly ash deposits is a current need to mitigate all environmental problems of fly ash in India and other countries. So, it is very important to remove heavy metals from these sites. A vegetative cover is a remedial technique to stabilize coal fly ash landfills and to physically and chemically immobilize heavy metals present in fly ash [6]. Numerous

plant species have been identified and tested for their traits in the uptake and accumulation of different heavy metals [7] and bioaccumulation potential of fly ash grown plants for the remediation of heavy metals of fly ash dumps [8-9]. The knowledge about the abilities of different plant species or tissues to absorb and transport metals under different conditions will provide insight into choosing appropriate plants for phytoremediation of the polluted sites.

Recently, some naturally growing plants on fly ash basins were evaluated for their phytostabilization/ revegetation potential with special reference to raising rural livelihoods and maintaining ecosystem services [10]. Few studies have been reported regarding natural vegetation on fly ash deposits across the world [11-12], but very less is known about the phytodiversity of these fly ash deposits. Naturally growing plant species seem to be a potential tool for the restoration of fly ash deposits in the present scenario because the plants growing naturally on fly ash deposits/ contaminated soil respond better and can survive easily in comparison to introduced species from other areas [13]. Keeping in view, the present work was undertaken to study the phytodiversity of fly ash deposits for identification of potential plant species found in and around the ash deposits of NALCO, Odisha, India for the restoration of Fly ash dumps.

## MATERIAL AND METHODS

### Study Area

For the study of phytodiversity, survey of vegetation colonizing fly ash deposits of National Aluminum Company Limited (NALCO), Koraput, India was undertaken during 2014-2015. Fly ash pond of NALCO is located at $18^0$46'14.27"N to $82^0$53'04.53"E which is nearly 5 km away from the Aluminum Refinery Plant (Fig. 1). Analysis for different physicochemical properties of fly ash was carried out in the laboratory. The nature of the fly ash was alkaline (pH=8.70±0.10). The Electrical conductivity and moisture content of fly ash was 158±13 µMho $cm^{-1}$ and 65±5 % respectively.

### Vegetation survey and collection of ecological data

An intensive survey of vegetation was conducted during 2014-2015 to collect naturally growing plant species during different seasons on fly ash dump sites. Quantitative assessment was done by laying 1 $m^2$ quadrates. The quadrates were randomly placed on 10 points. In each quadrate, the number of individuals of each species was counted, and this information has been further used to calculate frequency, density and dominance [14].

The important value index (IVI) for the species was expressed as the sum of total of relative frequency, relative density and relative dominance [15]. The plants were identified with the help of flora books (The Botany of Bihar and Orissa by Haines [16] and The Flora of Orissa by Saxena and Brahmam [17]) and visiting the Herbarium of the IMMT (RRL), Bhubaneswar. Plants were enumerated alphabetically according to their scientific name with latest available nomenclature with scientific name, family, local name and habit.

Frequency = No of plot in which species occurs/Total no. of plot sample
Density= Total no. of individual in all the sampling unit/ Total no. of sampling unit studied.
Dominance= Total basal area / No of plot in which species occurs

**Table 1. Phytodiversity on fly ash deposit of NALCO, Koraput, India.**

| Sl. No. | Scientific Name | Family | Common Name | Habit |
|---|---|---|---|---|
| 1 | *Aeschynomene aspera* L. | Fabaceae | Pith plant | Shrub |
| 2 | *Ageratum conyzoides* L. | Asteraceae | Goat weed | Herb |
| 3 | *Alternanthera philoxeroides* (Mart.) Griseb. | Amaranthaceae | Alligator weed | Herb |
| 4 | *Alternanthera sessilis* L. | Amaranthaceae | Sessile joyweed | Herb |
| 5 | *Aristida setacea* Retz. | Poaceae | Churchmouse threeawn | Herb |
| 6 | *Blumea lacera* (Burn.f.)DC. | Asteraceae | Blumea | Herb |
| 7 | *Calotropis gigantea* L. | Apocynaceae | Milk weed | Shrub |
| 8 | *Centella asiatica* L. | Apiaceae | Centella | Herb |
| 9 | *Chromolaena odorata* (L.) R.M. King & H.Rob. | Asteraceae | Siam weed | Shrub |
| 10 | *Commelina benghalensis* L. | Commelinaceae | Benghal day flower | Herb |
| 11 | *Conyza Canadensis* L. | Asteraceae | Horseweed | Herb |
| 12 | *Crotalaria striata* DC. | Fabaceae | Rattlepod | Shrub |
| 13 | *Cynodon dactylon* (L.) Pers. | Poaceae | Bermuda grass | Herb |
| 14 | *Cyperus cuspidatus* Kunth. | Cyperaceae | Coastal plain flatsedge | Herb |
| 15 | *Eriochloa procera* Retz. | Poaceae | Spring grass | Herb |
| 16 | *Lantana camara* L. | Verbenaceae | Wild sage | Shrub |

| | | | | |
|---|---|---|---|---|
| 17 | *Mimosa pudica* L. | Fabaceae | Sleepy plant | Herb |
| 18 | *Parthenium hysterophorus* L. | Asteraceae | White top weed | Herb |
| 19 | *Pennisetum pedicellatum* Trin. | Poaceae | Desho grass | Herb |
| 20 | *Perotis indica* (L.) Kuntze | Poaceae | Indian comet grass | Herb |
| 21 | *Polygonum glabrum* Willd. | Polygonaceae | Knot weed | Herb |
| 22 | *Setaria pumila* (Poir.) Roem. & Schult. | Poaceae | Pigeon grass | Herb |
| 23 | *Sida cordifolia* L. | Malvaceae | Flannel weed | Herb |
| 24 | *Solanum nigrum* L. | Solanaceae | Black nightshade | Herb |
| 25 | *Solanum torvum* Sw. | Solanaceae | Turkey berry | Shrub |
| 26 | *Spilanthes paniculata* Wall. ex DC. | Asteraceae | Phakpet | Herb |
| 27 | *Tridax procumbens* L. | Asteraceae | Tridax daisy | Herb |
| 28 | *Typha angustifolia* L. | Typhaceae | Narrow leaf cattail | Herb |
| 29 | *Vernonia cinerea* (L.) Less. | Asteraceae | little ironweed | Herb |
| 30 | *Woodfordia fruticosa* (L.)Kurz | Lythraceae | Fire-flame bush | Shrub |

**Table 2. Quantitative parameters of plant species on the fly ash deposit.**

| Sl. No. | Species | F | D | DO | RF | RD | R DO | IVI |
|---|---|---|---|---|---|---|---|---|
| 1 | *Aeschynomone aspera* | 20 | 0.5 | 5.0 | 2.59 | 1.2 | 2.83 | 6.61 |
| 2 | *Ageratum conyzoides* | 50 | 2.6 | 2.0 | 5.10 | 9.7 | 16.8 | 31.6 |
| 3 | *Alternanthera philoxeroides* | 20 | 1.7 | 5.0 | 2.59 | 4.4 | 2.83 | 9.82 |
| 4 | *Alternanthera sessilis* | 60 | 6.4 | 1.6 | 7.79 | 15.2 | 0.9 | 23.92 |
| 5 | *Aristida setacea* | 10 | 0.5 | 10.0 | 1.29 | 1.2 | 5.66 | 8.14 |
| 6 | *Blumea lacera* | 60 | 1.5 | 1.66 | 7.79 | 3.5 | 0.94 | 12.3 |
| 7 | *Calotropis gigantea* | 10 | 0.1 | 10.0 | 1.29 | 0.2 | 5.66 | 7.18 |
| 8 | *Centella asiatica* | 10 | 1.0 | 10.0 | 1.29 | 2.4 | 5.66 | 9.33 |
| 9 | *Chromolaena odorata* | 20 | 0.6 | 5.0 | 2.59 | 1.4 | 2.83 | 6.84 |
| 10 | *Commelina bhenghalensis* | 10 | 0.5 | 10.0 | 1.29 | 1.2 | 5.66 | 8.14 |
| 11 | *Conyza Canadensis* | 10 | 1.5 | 10.0 | 1.29 | 3.6 | 5.66 | 10.52 |
| 12 | *Crotalaria striata* | 10 | 0.2 | 10.0 | 1.29 | 0.5 | 5.66 | 7.42 |
| 13 | *Cynodon dactylon* | 40 | 2.0 | 2.5 | 5.19 | 4.8 | 1.41 | 11.36 |
| 14 | *Cyperus cuspidatus* | 20 | 0.7 | 5.0 | 2.59 | 1.7 | 2.83 | 7.08 |
| 15 | *Erichola procera* | 20 | 2.4 | 5.0 | 2.59 | 5.7 | 2.83 | 11.13 |
| 16 | *Lantana camara* | 20 | 0.4 | 5.0 | 2.59 | 0.9 | 2.83 | 6.37 |
| 17 | *Mimosa pudica* | 80 | 4.1 | 1.3 | 10.38 | 9.7 | 0.70 | 20.84 |
| 18 | *Parthenium hysterophorus* | 40 | 1.3 | 2.5 | 5.19 | 3.1 | 1.41 | 9.67 |
| 19 | *Pennisetum pedicellatum* | 30 | 1.3 | 3.3 | 3.89 | 3.1 | 1.88 | 8.86 |
| 20 | *Perotis indica* | 40 | 2.8 | 2.5 | 5.19 | 6.6 | 1.41 | 13.26 |
| 21 | *Polygonum glabrum* | 10 | 0.4 | 10.0 | 1.29 | 0.9 | 5.66 | 7.90 |
| 22 | *Setaria pumila* | 30 | 2.4 | 3.3 | 3.89 | 5.7 | 1.88 | 11.48 |
| 23 | *Sida cordifolia* | 20 | 0.9 | 5.0 | 2.59 | 2.1 | 2.83 | 7.56 |
| 24 | *Solanum nigrum* | 10 | 0.2 | 10.0 | 1.29 | 0.4 | 5.66 | 7.42 |
| 25 | *Solanum torvum* | 10 | 0.1 | 10.0 | 1.29 | 0.2 | 5.66 | 7.18 |
| 26 | *Spilanthes paniculata* | 20 | 2.1 | 5.0 | 2.59 | 5.0 | 2.83 | 10.42 |
| 27 | *Tridax procumbens* | 40 | 2.1 | 2.5 | 5.19 | 5.0 | 1.41 | 11.6 |
| 28 | *Typha angustifolia* | 10 | 0.6 | 10.0 | 1.29 | 1.4 | 5.66 | 8.37 |
| 29 | *Vernonia cinerea* | 10 | 0.4 | 10.0 | 1.29 | 0.9 | 5.66 | 7.90 |
| 30 | *Woodfordia fruticosa* | 30 | 0.7 | 3.3 | 3.89 | 1.6 | 1.88 | 7.43 |

F: Frequency, D: Density, DO: Dominance, RF: Relative Frequency, RD: Relative Density, R DO.: Relative Dominance, IVI: Important value index.

**Figure 1. Study site showing the fly ash deposit of NALCO, Koraput, Odisha, India**

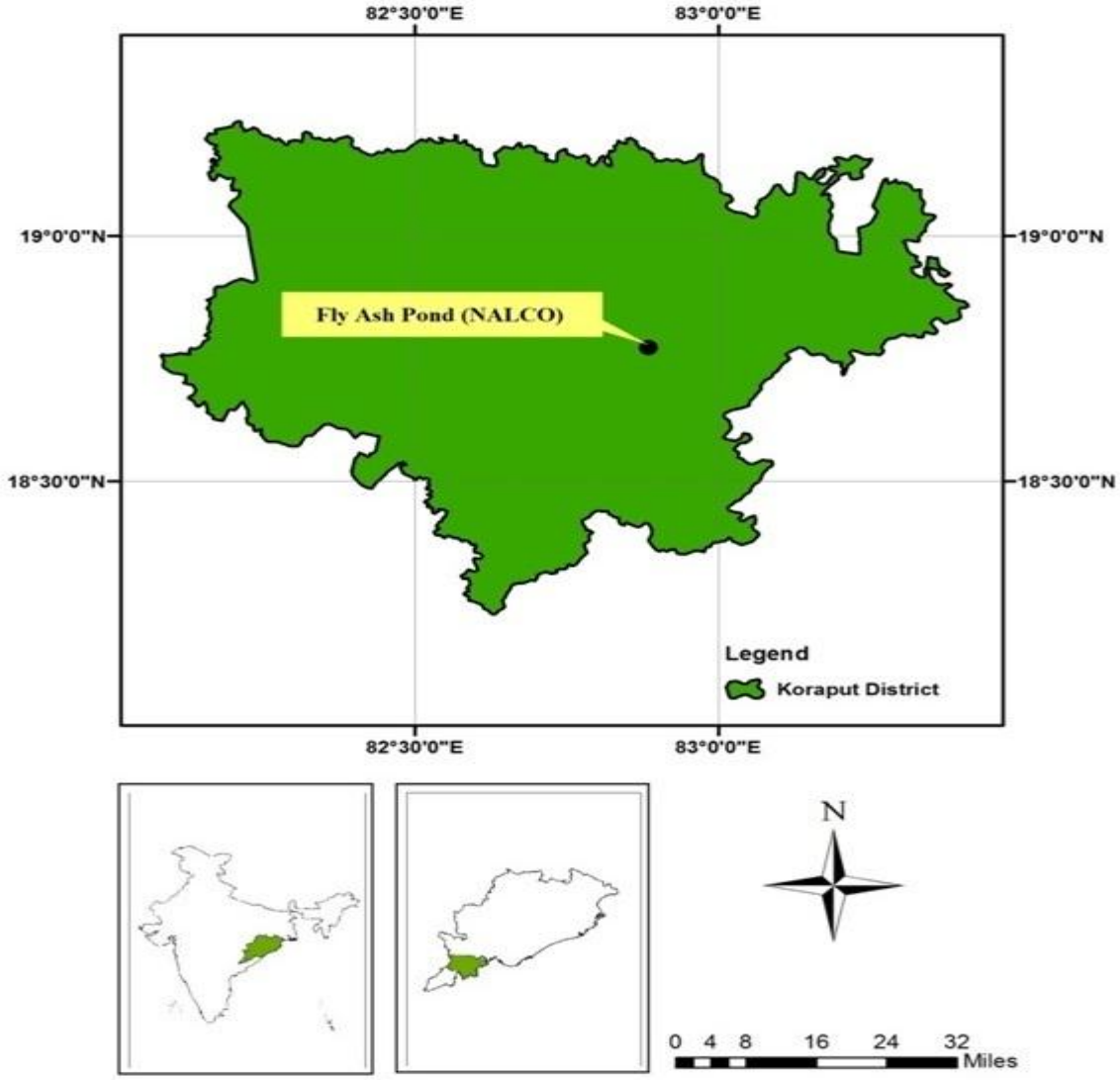
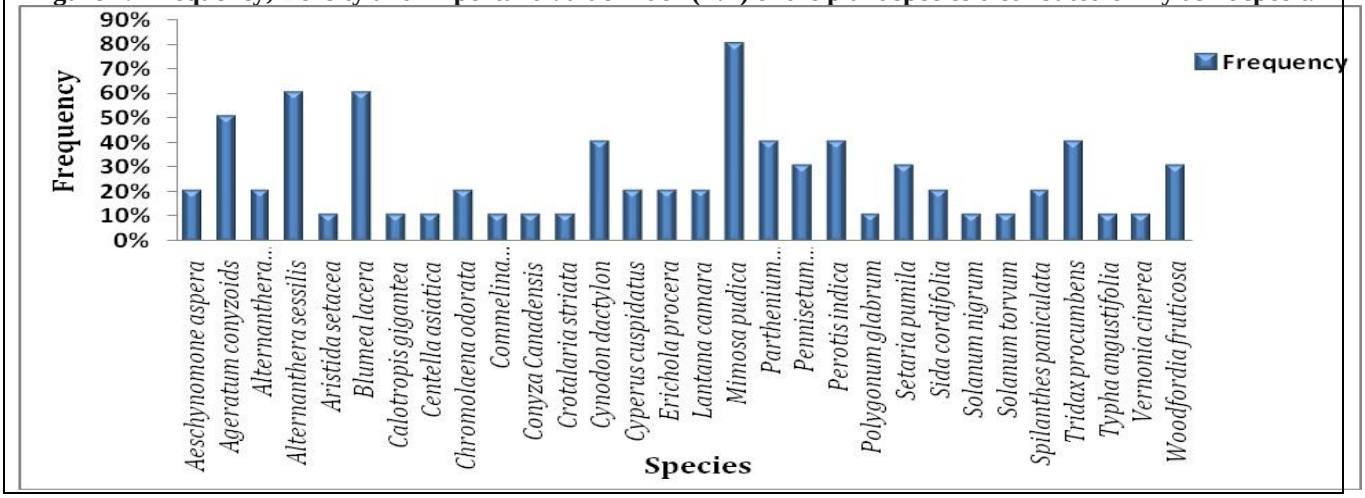
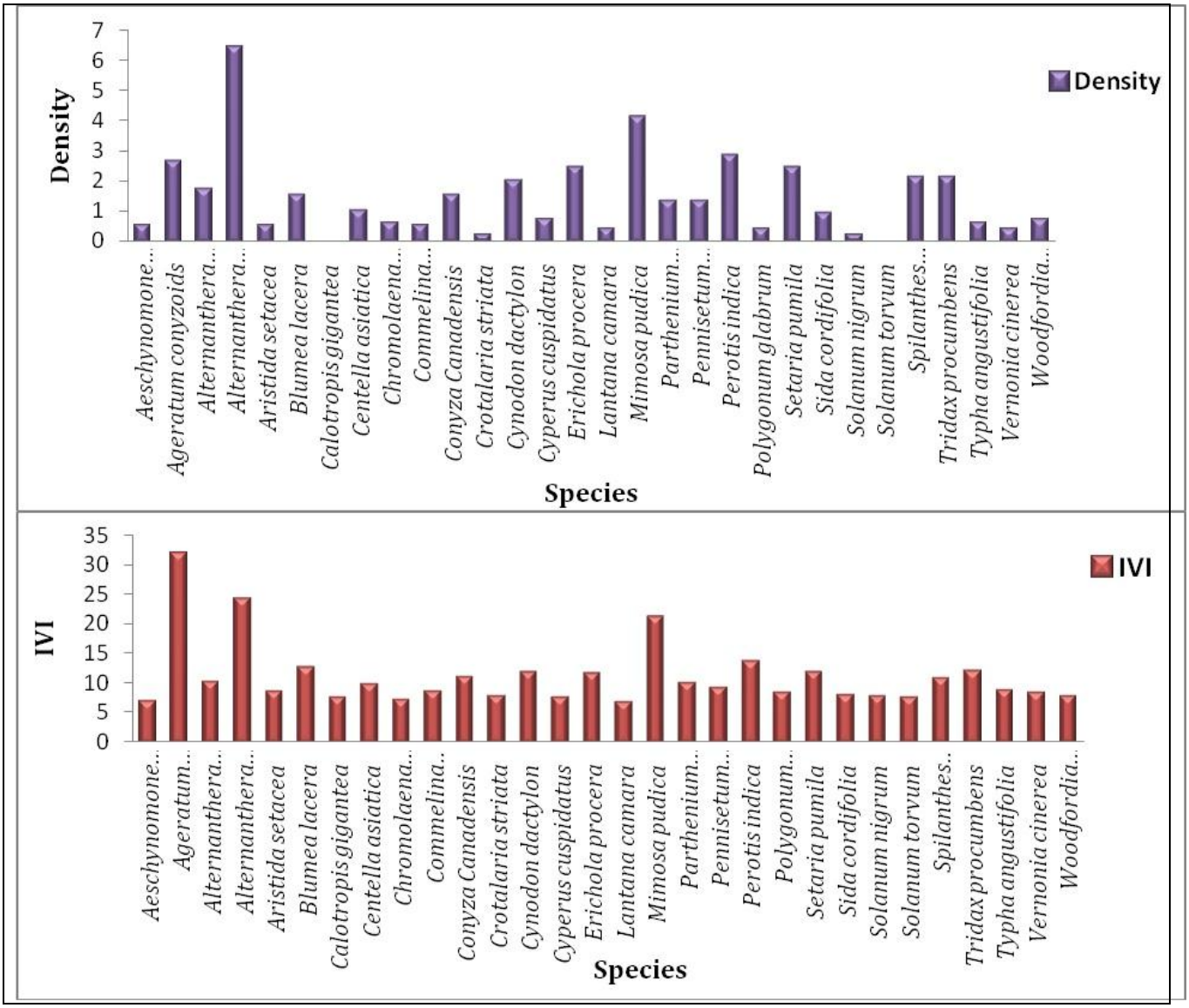



**Figure 2. Frequency, Density and Important Value Index (IVI) of the plant species distributed on fly ash deposit.**






## RESULTS AND DISCUSSION

In the present study, a sum of 30 plant species distributed in 28 genera belonging to 14 different families was observed (Table 1). Most of the plants were distributed under family Asteraceae (8) followed by Poaceae (6) and Fabaceae (3) and 7 species of plants are shrubs and 23 plant species are herbs. Different quantitative parameters like frequency, density, dominance and IVI of each plant species was presented in Table 2. The highest frequency of plant as revealed from quantitative structure was found in *Mimosa pudica* (80%) followed by *Alternanthera sessilis* (60%) *and Blumea lacera* (60%) (Fig.1) similarly, the highest density was observed in the *Alternanthera sessilis* (6.4) followed by *Mimosa pudica* (4.1*) and Perotis indica* (2.8) (Fig. 2). Furthermore, the highest dominance value was observed in the plant *Aristida setacea and Calotropis gigantea* (10) followed by *Centella asiatica, Conyza canadensis, Crotalaria striata, Polygonum glabrum, Solanum nigrum, Solanum torvum, Typha angustifolia* and *Vernonia cinerea*. The Importance Value Index determines the extent of dominance of a species in the population structure was presented in Fig. 1. It is said that species with the more importance values are the leading dominant species of the ecosystem. According to the IVI value, the leading dominant plant species of the study area are *Ageratum conyzoides* (31.6) followed by *Alternanthera sessilis* (23.92*), Mimosa pudica* (20.84), *Perotis indica* (13.26) and *Blumea lacera* (12.3*).*

Naturally colonized invasion on fly ash dumping sites take place slowly due to harsh environmental conditions like extreme alkalinity, heavy metal toxicity and lack of nitrogen and available phosphorus [18]. Naturally growing plants seem to be the most appropriate

colonizers on fly ash dumping sites but they must have some desirable characters such as perennial nature, extensive root system, self-propagation, unpalatable and tolerance to high pH and toxic metals of fly ash or having strong vigour to tolerate the local adverse conditions [13]. During the course of succession, seeds of almost every plant species growing in nearby areas are transported to fly ash dumping sites by means of wind and biological agents. Seeds of many species germinate in their respective seasons of germination, whereas seeds of other species fail to germinate in appropriate moisture and temperature regimes. After germination only some species having tolerance against the unfavourable conditions of fly ash survive in these sites. These reported species growing naturally on fly ash dumping sites may serve as the potential tool for fly ash dumps' restoration.

Many of the reported species during the present study are also reported by other researchers on different fly ash dumping sites from the different parts of the country, which shows the potential of these species for phytoremediation of fly ash dumping sites. Heavy metal accumulation pattern in some reported species shows that accumulated metal is highly localized in the root zone in comparison to areal parts [19, 10] and their suitability for phytostabilization. These species are ecologically very important as they reduce erosion by binding fly ash particles, add organic matter and make the site suitable for the germination of forthcoming seeds of other species. The presence of these plant species on barren fly ash dumps also helps in the biostabilization of heavy metals, providing a bioaesthetic landscape for local residents, generation of bio-resource useful to villagers and carbon sequestration in ash soil–plant system of fly ash dumps [13]. This process should be enhanced by identifying potential plant species and by making artificial supply of their seeds on fly ash dumping sites.

## CONCLUSION

From the study it is evident that species like *Ageratum conyzoides*, *Alternanthera sessilis*, *Mimosa pudica*, *Perotis indica*, *Blumea lacera*, *Aristida setacea*, *Calotropis gigantea*, *Centella asiatica*, and *Crotalaria striata* are identified as potential plant species for fly ash deposits' restoration. Furthermore, the naturally colonized species can be used for the phyto-restoration during a re-vegetation plan of new fly ash deposits. This is perhaps the easiest, cost-effective and eco-friendly technology for the restoration.

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## REFERENCES

1. Gautam S, Singh A, Singh J and Shikha. (2012). Effect of Fly ash Amended Soil on Growth and Yield of Indian mustard (*Brassica Juncea*). *Advances in Biores*, 3, 39-45.
2. Pandey VC, Prakash P, Bajpai O, Kumar A and Singh N. (2014). Phytodiversity on fly ash deposits: evaluation of naturally colonized species for sustainable phytorestoration, *J of Env Sci and Pollution Res*, 22(4), 2776-2787.
3. Gupta DK, Rai UN, Tripathi RD and Inouhe M. (2002). Impacts of fly-ash on soil and plant responses. *J of Plant Res*, 115,401-409.
4. Pandey VC, Singh JS, Singh RP, Singh N and Yunus M. (2011). Arsenichazards in coal fly ash and its fate in Indian scenario. *Resource Con and Recycling*, 55, 819–835.
5. Rau N, Mishra V, SharmaM, Das MK, Ahaluwalia K and Sharma RS. (2009). Evaluation of functional diversity in rhizobacterial taxa of a wild grass (*Saccharum ravennae*) colonizing abandoned fly ash dumps in Delhi urban ecosystem. *Soil Biol and Biochem*, 41, 813–821.
6. Bilski J, McLean K, McLean E, Soumaila F, Lander M. (2011). Environmental health aspects of coal ash phytoremediation by selected crops, Int j of Env Sci, 1, 2028-2036.
7. Stoffella XY, Lone MI, Zhen-li HE and Peter J. (2008). Phytoremediation of heavy metal polluted soils and water: Progresses and perspectives. *Journal of Zhejiang University SCIENCE B*, 9(3), 210-220.
8. Gupta AK, Sinha S. (2008) Decontamination and/or revegetation of flyash dykes through naturally growing plants. *J of Hazardous Materials*, 153, 1078–1087.
9. Kumari A, Pandey VC. and Rai UN. (2013). Feasibility of fern *Thelypteris dentata* for revegetation of coal fly ash landfill. *J of Geochem Exploration*, 128, 147–152.
10. Pandey VC, Singh K, Singh RP and Singh B. (2012). Naturally growing *Saccharum munja* on the fly ash lagoons: a potential ecological engineer for the revegetation and stabilization. *Ecological Engineering*, 40, 95–99.
11. Mulhern DW, Robel RJ, Furness JC and Hensley DL. (1989). Vegetation of waste disposal area at a coal fired power (plants) on fly ash. *Env Sci and Technol*, 13, 311–315.

12. Mustafa B, Hajdari A, Krasniqi F,Morina I, Riesbeck F and Sokoli A. (2012). Vegetation of the ash dump of the "Kosova A" power plant and the slag dump of the "Ferronikeli" Smelter in Kosovo. *Res J of Environ and Earth Sci*, 4(9), 823–834.
13. Pandey VC and Singh K. (2011). Is *Vigna radiata* suitable for the revegetation of fly ash landfills?. *Ecological Engineering*, 37, 2105–2106.
14. Curtis JT and McIntosh RP. (1950). The interrelations of certain analytic and synthetic phytosociological characters. *Ecology*, 31, 434-455.
15. Dash PK, Panda D, Dhal NK, Rout NC, Muduli SD and Rao KS. (2007). Quantitative assessment of true mangroves present at Bhitarkanika wild life sanctuary, Orissa, India. *Ecology, Env and Cons*, 13(2), 402-408.
16. Haines H H. (1921-25). The botany of Bihar and Odisha, Sri Gauranga Press, Calcutta.
17. Saxena HO. and Brahmam M. (1994-96). The Flora of Orissa, Orissa Forest Development Corporation Ltd. and Regional Research Laboratory, Bhubaneswar.
18. Haynes R J. (2009). Reclamation and revegetation of fly ash disposal sites – challenges and research needs. *J of EnvironManagement*, 90, 41 –53.
19. Maiti S. and Jaiswal S. (2008). Bioaccumulation and translocation of metals in the natural vegetation growing on fly ash deposits: a field study from Santaldih thermal power plant, West Bengal, India. *Environ Mon Assessment*, 136, 355 – 370.