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Efficiency of *Prosopis juliflora* for phytoremediation of fly ash heavy metals

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Abstract:

Coal being major fuel for energy production in most of the developing country contributes in generation of enormous amount of byproduct named fly ash. Fly ash disposal and treatment is major problem till date owing to its chemical and physical nature. Efficiently growing natural weed species Prosopis juliflora in the metal enriched pond ash reflects its potential to tolerate fly ash metals also its characteristics to survive in harsh environment. Prosopis juliflora was assessed for phytoextraction potential of Cr, Cd, Fe, Cu, Ni, Pb. Mixture of fly ash and soil was made in ratio 0%, 25%, 50%, 75%, and 100%. Soil without fly ash was used as control. Results showed the efficiency of Prosopis juliflora for heavy metals of fly ash.

Keywords: Fly ash, Phytoextraction, Heavy metals.

I. Introduction

Coal plays an important role in energy generation all around the world. Due to enormously increasing demand of electricity quantity of fly ash generation is also increasing. About 225 million tons of annual production of coal is there in India. Approx 75-80% of electricity generation in India is by coal based thermal power plants. During combustion of coal at high temperature organic fraction of coal burns and inorganic particles agglomerates to for solid substance known as fly ash before leaving furnace of combustion unit. Fly ash is composed of several small size particles, glassy substances, some unburned carbon particles together with heavy metals. Depending on parent coal pH of fly ash may be acidic or alkaline with low nutrient content. This fly ash generated at thermal power plants may be dumped off in landfill sites by dry disposal system using trucks etc. or may be flown off in for of slurry through pipelines into artificial pond. In both disposal system fly ash comes occupies enormous valuable land and come in our environment for contaminating our ecosystem altogether. Fly ash is potential contaminator of all spheres. When fly ash is released in open area is heavy metals are released into environment. Presence of heavy metals in our environment or water bodies tends to enter our food chain. By different remediation process we can emphasize on metal recovery rather than traditional approach of disposal. This produced fly ash utilization share is much lower as compared to generation percentage. Therefore its remediation comes into picture. Biological treatments using flora and fauna are one of the best methods for remediation of heavy metals. This remediation technique may be grouped into two types.

1. Ex-Situ method

This method is applied to remediate the polluted soil. It requires a contaminated soil remediation by excavation and detoxification or destruction of physical and chemical contaminant. This causes immobilization, stabilization or solidification of contaminant.

2. In- situ method

In this method contaminants are transformation or destroyed on site itself. Bioavailability of contaminant is reduced, using flora and fauna.

Phytoremediation

In this method plants are utilized for metal removal or for detoxification of environmental contaminants. Popularly it is of following types:-

1. Rhizofiltration/Phytofiltration

In this process metals from contaminated sites are absorbed by root system of plants. After fixed time intervals whole plants may by harvested.

2. Phytoextraction

In this process plants are grown in contaminated site and after fixed time aerial part of plant can be harvested for metal removal.

3. Phytostimulation/ Phytodegratdation

In this process plant stimulates degradation of contaminants through secretions of some chemicals in rhizosphere or with the help of microbes contaminants can be degraded.

4. Phytovolatilization

In this process plants take up contaminants from contaminated site then transform them into volatile form and transform them into atmosphere.

5. Phytodesalination

The use of halophytic plants for removal of excess salts from saline soil (Manousaki and Kalogerakis 2011; Ali et al 2013)

Table1: Advantage and disadvantage of Phytoremediation (Source: M.Ghosh and S.P.Singh2005)

No.	Advantages	Disadvantages
1	Various organic and inorganic compounds can be amended with this technique	Restricted to the root zone of plant
2	It can be applicable either in situ or ex situ contaminated sites	It may require many years for remediating a contaminated site
3	Soil disturbances can be avoided in, in situ method of remediation	May not good option of highly contaminated sites treatment
4	Harvested plant can be further utilized as bio-ore for metal extraction	Biomass used in remediation can be considered as hazardous waste, thus needs proper disposal.
5	Contaminants spreading can be avoided in air and water	Environmental conditions can be limiting factors
6	Expensive equipments are not required	Non native species introduction may affect local biodiversity of area
7	Thermal energy can be generated used these plants in large applications	It is a great cause of concern for utilization of contaminated plant biomass
8	Comparatively low cost	elongated remediation movements

II. Material method

Sample collection

Fly ash samples were collected from Gandhinagar thermal power plant located at 23◦14' 57″ N latitude and 72◦ 40' 15″E longitude. Soil samples were collected along the banks of Sabarmati River from a depth of about 30 cm. Before drying of soil samples stones and plant tissues were removed in the laboratory. 2 mm stainless steel sieve was used to screen soil and later stored in plastic bags. Seeds of *Prosopis juliflora* were chosen for present study.

Experimental approach

Experiment was conducted in pot in laboratory using different concentration of fly ash with soil 0%, 25%, 50%, 75%, 100% respectively. Seeds were germinated in triplicate in pots with no artificial light or temperature nor artificial fertilizers were used during course of experiment. Harvested plants were washed with Millipore water and later analyzed for heavy metal accumulation.

Physicochemical analysis

pH, Total nitrogen, Alkalinity, P, Moisture content, Ammonia, Bulk density, Nitrite, Porosity, Nitrate, Porosity, Conductivity, Sulphate, Cation exchange capacity, water holding capacity, organic carbon were determined using standard methods. Concentrations of selected metals were determined by atomic absorption spectrophotometer.

III. Result and discussion

Parameters like pH, Alkalinity, porosity, EC, TDS, water holding capacity, of different amendments showed (Table1) the increased value with the increased concentration of fly ash. Value of moisture content, bulk density. organic carbon, Cation exchange capacity, Nutrient content showed decreased value. lack of organic content in fly ash, lower value of nitrogen and phosphorous makes fly ash to be nutritive deficient substrate.

Table1: Physico-chemical analysis of fly ash and its amendments

Amendments ⇨ / Parameters ⇩	0%	25%	50%	75%	100%
Colour	Brown	Light brown	Greyish brown	Light gray	Gray
pH	7.58±.02	7.88±.02	7.94±.02	8.06±.01	8.93±.03
Alkalinity	95±.04	160±.02	136±.01	150±.01	161.5±.04
EC	146.05±.01	172.67±.01	204.5±.12	344±.01	449.25±.02
TDS	70.4±.01	85.75±.02	100.3±.02	154.25±.01	278±.01
Moisture content	1.02±2.5	0.396±.01	0.368±.01	0.286±.01	0.150±.01
Organic carbon	0.94±1.3	0.9±.02	0.83±.01	0.74±.02	0.61±.01
Porosity	45±.02	49.71±.01	54.83±.02	59.08±.02	60.13±.02
WHC	31.07±.20	30.02±.14	30.47±.01	35.79±.12	40.27±.15
BD	2.938±.02	2.231±.02	2.128±.03	1.892±.03	1.704±.02
CEC	4.04±.18	3.08±.43	2.54±.06	1.04±.01	0.56±.01
Nitrate	21.9±.1	20.12±.83	19.7±.03	16.45±.95	11.00±.90
Sulphate	32.55±.3	26.42±.26	19.02±.2	15.73±.13	11.05±.16
Phosphate	19.01±.06	17.05±.03	11.12±.09	9.54±.066	5.14±.055

Values in triplicate ± SD

Gupta et al., (2007) reported enhanced pH value with increased fly ash ratio due to soluble cations precipitation in the fly ash amended soil. Soil amended with Fly ash enhanced EC value

with the increased concentration of minor and major inorganic constituents of fly ash (Eary *et al*., 1990). Fly ash significantly increases water holding capacity of the soil mixture though fly ash is bad in water retention property (Chang *et al*., 1977). Soil with Fly ash medium has been reported for better soil porosity and in turn water holding capacity is increased (Gupta *et al*., 2002) and bulk density is decreased (Page *et al*., 1979). Similar results for CEC has been reported for decrease value of CEC with increased concentration of fly ash (Gupta *et al*., 2007).

Results (Table2) showed increased concentration of fly ash has negative effect on plant biomass i.e. with increase concentration of fly ash root length and shoot length decreased. Inverse correlation was seen between growth/ biomass and fly ash amendments. There are various studies that shows increased biomass at lower amendments of fly ash while higher amendments may have become toxic hindering growth of plant (Gupta *et al.*, 2007).

Table2: Physiological traits of plant at various amendments of fly ash.

Concentration (%)	Root length	Shoot length	Biomass	
			Root weight	Root weight
0	8.0±.14	17.4±.21	2.80±.44	3.71±24
25	4.9±.16	8.0±.05	2.98±.57	3.40±.30
50	4.5±.14	7.10±.06	1.82±.90	2.68±.07
75	4.0±.15	5.60±.07	1.32±.72	2.07±.11
100	3.6±.02	4.80±.12	1.00±.94	3.02±.08
All values are mean of triplicates ±S.D.				

The data in Table3 incorporate the evaluation of heavy metal contents in the collected soil samples from river bed site. A comparision of heavy metal content between control soil and amendments showed that selected metal (Cr, Cd, Fe, Cu, Ni,Pb) level were increased with increased concentration of fly ash.

Table3: Heavy metal concentration in soil, fly ash and their amendments

Concentration (%)	0	25	50	75	100
Cadmium	.87±.018	.99±.019	1.02±.021	1.89±.004	2.81±.005
Chromium	9.03±.016	15.91±.019	15.45±.050	16.19±.002	18.1±.007
Iron	21.56±.05	27.38±.02	35.71±.02	116.8±.06	224.67±.06
Copper	5.97±.04	6.35±.12	7.38±.05	8.94±.05	10.52±.07
Nickel	2.3±.06	5.67±.02	6.47±.07	7.8±.03	8.24±.03
Lead	2.64±.05	3.47±.12	3.51±.06	3.64±.05	4.72±.01

Values in triplicate ± SD

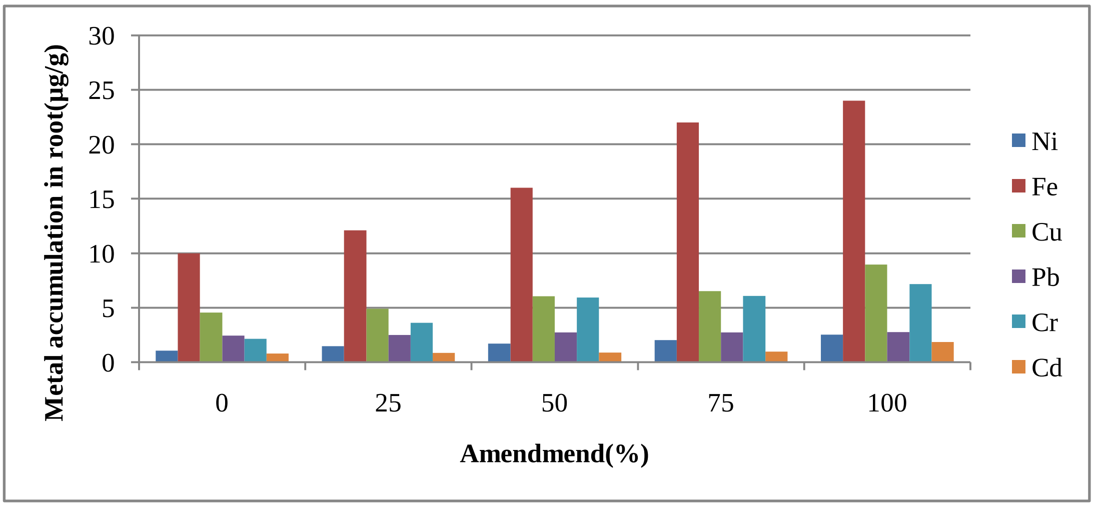

Figure1: Heavy metal accumulation in root of plant

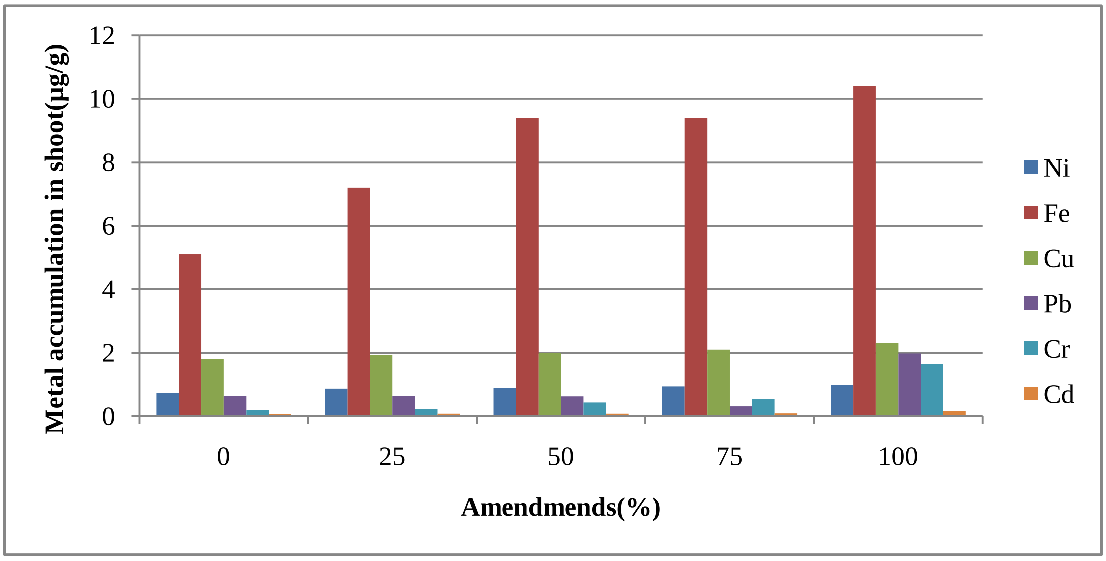

Figure2: Heavy metal accumulation in shoot of plant

Heavy metal acumulation in plant showed increased uptake of metals in both roots and shoot of plant with increasing concentration of fly ash. Metal concentration was lowin shoot as compared to root. Concentration of metals in plants vary with plant species (Petreseu and Bilala 2007; Lacatusu et al 2009). So we can conclude this weed specie is efficiently capable for remediation of heavy metals from contaminated site.

IV. Conclusion

Coal which is expected to major fuel for energy generation will in turn be generating by product called fly ash in near future too. So its need to be prepared for increasing its utilization percentage also for its remediation part. Phytoremediation which is a promising technique for metal remediation need to be explored more. Indeed we are working a lot in the field of phytoremediation. Still biotechnological approaches are needed to work out more detail forl to explore more understanding and enhancing phytoremediation potential of plant for metal removal. In this direction remediation using weed species can be more useful for sustainable future.

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