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Assessment of phytoremediation potential of native grass species growing on red mud deposits

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ABSTRACT

The present study deals with the remediation of red mud deposits through the naturally growing native grass species. On the basis of visual observation we noticed that *Saccharum bengalense* Retz. is a dominant grass species of vegetation on red mud deposits. The results showed that most of the elements are stabilized in root part of the plant except Fe, Zn and Cd. Therefore, it reveals that *S. bengalense* has the capability for phytostabilization of red mud deposits, is a promising species for the remediation and management of red mud deposits.

1. Introduction

Ever increasing amount of solid waste dumps like fly ash, red mud, sewage sludge and other mining wastes has become inevitable and consequences the toxicity of ecosystems and creates harmful environment. Due to increasing amount of these solid wastes, heavy metal pollution becomes a topic of social challenge. Furthermore heavy metal pollution creates unfavourable condition on soil microbes and plant growth just because of its inauspicious substrate chemistry (Pandey and Singh, 2012). Red mud is one of the main solid waste products generated from alumina industry, which inhibits the plant growth due to its high alkalinity and salinity (Mishra et al., 2016; Alshaal et al., 2013). Abandoned red mud land causes dust, air and water pollution which consequences the harmful environment for humans and livestock. Therefore, rehabilitation approach for these abandoned lands is very necessary that would make possible the substrate fertility and mitigation of global warming through phytorestoration (Pandey and Singh, 2012; Verma et al., 2014). Recent practices that would initiate the restoration are also quite beneficial for the biodiversity assessment of that barren dump sites. Towards the recovery of these sites, it is important concept that plant–microbe interactions induce such changes in soil properties during early primary succession which initiates the development of a vegetation ecosystem (Knelman et al., 2012). Through rhizodeposition and uptake of nutrients plant roots significantly influence the nutrients availability in the plant rhizosphere (Koranda et al., 2011).

Apart from this some naturally growing plant species showed a great promise in view of their best adaptation against these type of derelict lands (Gupta and Sinha, 2008; Maiti and Jaiswal, 2008; Rau et al., 2009). Some plant species such as *Arundo donax L.* (giant reed), *Lolium perenne*, *Trifolium pratense*, *Agrostis stolonifera*, *Fescue longifolia*, *Holcus lanatus*, *Trifolium repens*, and *Trifolium pratense* have been tested to restore abandoned red mud deposit sites in vegetated area (Alshaal et al., 2013; Courtney and Mullen, 2009; Courtney et al., 2009). It is well known that naturally growing plant species has more capability to restore easily waste dump sites compared to introduced plant species because of inherent capability (Pandey and Singh, 2011; Pandey et al., 2015). *Saccharum bengalense* Retz. is native grass species belongs to poaceae family (Fig. 1). It is locally known as Munj, Baruwa grass. This grass has extensive deep root system and fastens colonization that makes its growth suitable on barren red mud land. Previously this grass species has also reported for their adaptation on the abandoned fly ash lagoons (Pandey et al., 2012; Chauhan and Ganguly, 2011). Thus, *S. bengalense* is identified as a promising grass species for rehabilitation and restoration purpose. Keeping all these points in mind, the main objective of this study was to evaluate the phytoremediation potential of this naturally growing native grass species on derelict red mud deposits. (i) elemental analysis in plant parts and substrate; (ii) correlation between plant parts and substrate; (iii) evaluation of bioconcentration and translocation factor.

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Fig. 1. Naturally growing grass species *Saccharum bengalense* Retz. on Red mud deposit site.

Table 1
Physicochemical characterization of abandoned Red mud deposits (Mean ± SD).

Chemical characteristics	Values (N = 5)
pH	11.67 ± 0.21
EC(μS cm^{-1})	5076 ± 11.55
Total P (μg g^{-1})	113.0 ± 2.65
WHC	58.14%
Porosity	2.72%
Elements (μg g^{-1})	
Fe	145,533.33 ± 57.74
Cu	110.0 ± 13.23
Mn	441.67 ± 2.89
Zn	235.0 ± 5.00
Cr	30.33 ± 0.29
Cd	56.83 ± 0.29
Pb	361.00 ± 8.32

2. Material and methods

2.1. Study site description

The plant and soil samples used in this study were collected from Hindalco Industries Pvt. Ltd. (lat. 24°12′0″N; long. 83° 65 2′0″E), Renukoot, a known iron rich site is situated in an area of Sonebhadra district of Uttar Pradesh, India. Annual rainfall measuring in this region is 1032 mm. Average temperature marks 32–46 °C in this area.

2.2. Collection of samples, preparations and chemical analysis

Rhizosphere (RS) and non-rhizosphere (NRS) RM samples of *S. bengalense* and their associated plant samples were collected in December 2014. These samples were collected on the basis of their coverage at site. RM samples were taken from the depth of (0 − 30) cm rooting zone. Homogenised red mud samples were oven dried and sieved by 2 mm stainless steel sieve and used to analyze the chemical parameters and elements. The pH and electrical conductivity (EC) of red mud were measured by using a pH meter and a conductivity meter (Orion Star A215), respectively. Water Holding Capacity (WHC) was analyzed by the method described by Black et al. (1965).

Collected plant samples were separated into three parts that is root, stem and leaf. These plant samples washed very carefully with deionised distilled water to remove adhered soil particles. After washing plant samples were oven dried at 80 °C overnight to obtain constant weight. Plant and Red mud samples (0.1 g) were digested for estimation of elements with 5:1 ratio of HNO3 and HClO4. After digestion process samples were filtered and volume was made up upto 50 ml with mili-Q water. Different elements concentrations were analyzed by atomic absorption spectrophotometer (AAS). Red mud total P in digested samples was analyzed by using the manual of Kalra and Maynard (1991).

2.3. Statistics

The results are expressed as mean ± standard deviation with three times independently using sufficient replicates. Pearson correlation coefficients applied between metal concentrations in the aboveground and underground tissues and soil factors with using Graph Pad prism software.

3. Result and discussion

3.1. Characteristics of abandoned Red mud site

Physicochemical properties and elemental analysis represented in Table 1. Red mud is highly alkaline in nature with an average pH of approximately 11.67. Solubility of salt content in red mud is represented as electrical conductivity (EC) of water extract. Average EC of non-vegetated Red mud was found 5076 (μS cm^{-1}).

The average concentration of total P in the non-vegetated Red mud was found 113.0 μg g^{-1}. Various elements are investigated in red mud and their accumulation trend was found in following order Fe > Mn > Pb > Zn > Cu > Cd > Cr. Here in this study between all heavy and essential elements Fe was found maximum. Additionally heavy metals concentration in red mud is low in comparison to essential elements and varied greatly. Pb concentration was found maximum among all heavy metals which may indicate that it comes from large source of contamination.

3.2. Elemental analysis in plant parts and substrate

All essential and heavy metal concentration (except Fe) in plant tissue (root, stem and leaf) and soil are shown in Fig. 2A, B. This data analyze that significantly, very higher concentration of Fe was found in soil in comparison to all other essential and heavy metals, that's why it is shown separately in Fig. 2A.

While on other hand high Mn and Pb content was observed in rhizospheric RM sample of *S. bengalense* when compare to the Cr, Cd and Cu content. This is just because the capacity of some plants which can colonize the some part of elements into the soil (Nouri et al., 2009). The compartmentalization of elements in the plant parts shows that *S. bengalense* accumulated higher content of Fe (3571.5 and 9043.33, 5871.67 μg g^{-1}) in their underground (Root) and aboveground (Stem and leaf) parts rather than other essential and heavy metals due to the maximum concentration of Fe present in this particular site. Higher Zn, Cu and Mn content were accumulated in the root of plant when compare to the heavy metals like Cd and Pb except Cr. *S. bengalense* is a monocotyledons category of plant which accumulate generally the higher concentration of Pb in their root part when compare to stem (Fitzgerald et al., 2003). As we know that Zn and Cd both elements are very important for absorption and transportation mechanism of plants. Here in this study Zn depresses the Cd uptake because of its higher affinity with the plasma membrane (Mengel and Kirkby, 2001; Hart et al., 2005). The concentration of elements in shoots were maintained at low level which represented that metal tolerating strategy is widely evolved in the plant species growing in metal enriched area.

3.3. Correlation between plant parts and substrate

Various external (soil associated) and internal (plant associated) factors are responsible for the uptake of elements into plants, when grown in metal enrich substrata. So here in this part Pearson correlation coefficients was measured between elemental concentrations in the underground and aboveground tissues and soil factors for determination of connection between plants and soil factors , which are given below in the Table 2.

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