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Review article: Comparative Advantage of Vetiver Grass for the Phytoremediation of Heavy Metal Contaminants

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Abstract
Application of plants for the rehabilitation of heavy metal contaminated areas has been studied in different countries. It is generally environmentally friendly and relatively cost effective; however, its efficiency is reported to depend on majorly on plant factors i.e. their response to conditions of contaminated area and their growth characteristics. Hence, the objective of this review is to investigate the efficiency of vetiver grass for the remediation of selected heavy metals compared to other selected plant species with respect to factors that are limiting their phytoremediation efficiency. Phytoremediation Studies conducted in field experiment and pot experiments in green house or open field were reviewed. Due to its high biomass production and tolerance to low PH and high heavy metal concentration vetiver was found to have higher phytoremediation efficiency compared to some hyperaccumulators and non-hyperaccumulators plants.
Keywords: Phytoremediation, Vetiver, Heavy metals

1. Introduction

Land and Water bodies' contamination with heavy metals are becoming a major environmental problem that is putting human and animal health at risk and threatening the ecosystem as well. Industrialization, intensive agriculture and mining activity increase are considered as the major source of these contaminants (Chen *et al*. 2004; Mmolawa, *et al* 2011). For instance, in the developing world improper disposal of industrial effluents are causing soil pollution while increase use of agrochemicals are contaminating the soil with non-essential heavy metals like cadmium which could be passed on into the food chain (Chen *et al* 2000). Likewise, a considerable amount of different metals is being released together with mining wastes (Sheoran, *et al*2012). These metals like Cd, Cr, Cu, Hg, Pb, and Zn could be integrated to the environment because of rain and they can contaminate downstream watersheds. They have a potential to cause DNA damage if they accumulate in human or animal body which result in carcinogenic effect (Hooda, 2007). Heavy metals are found naturally in the earth crust and their unique properties are that they have atomic density and atomic number greater than 5 $g{\cdot}cm^{-3}$ and 20 respectively (Adriano 2001; Jadia, and Fulekar 2008).

Therefore, decontamination of these metals from the environment has gained at most importance. Different kinds of interventions like chemical, physical or biological techniques have been developed in order to remediate the contaminated environment. However, the physical and chemical treatments apart from being expensive, they are reported to have adverse effect on the soil properties, destroying the biodiversity as well as making the soil unproductive. In contrast to that Phytoremediation which can be defined as the process, which uses green plants for the relief, transfer, stabilization or degradation of pollutants from soil, sediments, surface waters, and groundwater (Elekes , 2014; Paz-Ferreiro, 2014)is becoming an important and growing biological techniques used for the restoration of affected ecology which is also found to be environmentally friendly and potentially cost effective (Wong 2003).

Phytoextraction, phytostabilization, phytodegradation, rhizodegradation, rhizofilteration, Phytovolatalisation are the different types phytoremedation that are used by the plants during their remediation processes (Tangahu, *et al* 2011).Among them phytoextraction and phytostabilization are two most known techniques used by the plants for remediation of heavy metals (Laghlimi, *et al* 2015). Phytoextraction is the uptake of heavy metals by plant roots and translocating them to their aboveground biomass while phytostabilization is the immobilization or reduction of metals mobility. In this process the metals could be accumulated in the roots and/or adsorbed on the root surface and /or they could precipitate around the root zone. Plants having fast growth rate with large biomass production and high tolerance to heavy metals are reported to be ideal for the phytoextraction process (Marques 2009) while plants with well developed root system, high heavy metal tolerance and with low root to shoot translocation capacity are suitable for phytostabilization (Laghilimi, *et al* 2015).

Even though there are different kinds of plants like annuals, herbaceous, shrubs and trees (Elekes, 2014) that are showing phytoremediation capacity, grass species due to their inherent fast growth, high biomass production coupled with a well developed root system have showed potential application for the phytoremediation of heavy metals (Abaga *et al*. 2014,) In addition to that they can also accumulate large amount of metals in their biomass exhibiting their high tolerance for heavy metals(Xu and Wang 2013; Zhang *et al.* 2014). However, the phytoremediation efficiency of heavy metals by these plants is determined and controlled by a number of factors like soil property, plant species and climatic factors. One of the major soil properties that determine the remediation capacity of plants is the soil PH. A number of plants that are being used for phytoremediation due to their hyper accumulation potential are found to be less efficient at low as well as high soil PH(Truong, *et al* 2010).

In addition to that the morphological as well as physiological characteristics of these plants hinder their application under different environmental and contaminants conditions. Chishan Wu *et al* 2017 reported that the plants that are found to be hyperaccumulator of heavy metals were found to have less biomass, narrow adaptations, shallow rooted and mostly can tolerate one heavy metal at higher concentration while they are sensitive for others.

However, research reports on heavy metal remediation using plants identified the vetiver grass species as one of the choice plant for the phytoremediation soils and mines contaminate with heavy metals (Yang *et al.*, 2003). Its wide adaptation to extreme climatic conditions such drought, flood high and low PH, ability to and tolerance to high amount of different metals are the among the main characteristics of the plant in addition to its higher growth rate and well developed and deep rooting system(Danh *et al* 2009). For instance, it was used for remediation of highly Pb/Zn contaminated mine tailings in china. (Xia and Shu, 2001; Shu *et al*, 2002a),

Therefore, this review will be dealing with the potential application of vetiver grass for the phytoremediation of heavy metal contaminates considering its wide environmental adaptation, high level of tolerance for extreme soil properties and its morphological and physiological advantages over other selected plants that are commonly used for the phytoremediation of heavy metals.

2. Vetiver and Phytoremediation

2.1. Heavy Metals Accumulation

Field experiment and pot experiment in green house or open field that investigate about Phytoremediation potentials of vetiver with respect to other plant species have been reported by studies. According to Zhuang et al 2007 seven plant species which are considered to be hyper accumulator were compared with Vetiver on their phytoextraction potential of farm land which is moderately contaminated by Pb, (960±54 mg kg^{-1}) Zn(1,050±89 mg kg^{-1})and Cd(7.2±0.92 mg kg^{-1}). Hence, the highest Pb concentration was found in *Dianthus chinensis* plant (309mg/kg) followed by *Viola baoshanensis* (VB*)*(260mg/kg) while the least amount of Pb concentration was presented in *Rumex K-1*(43mg/kg). In the case of Zn up take the highest concentration was found in the tissue of *Sedum alfredii* (6280mg/kg) and the *Rumex crispus* plant accumulated the second highest concentration of Zn(2350 mg/kg) while the Rumex K-1 species again found to be the least accumulator. The vetiver grass was found to accumulate about 155 mg/kg and 480 mg/kg of Pb and Zn respectively. Likewise, in case of chromium the highest accumulation in dry weight basis was found in the VB species (46 mg kg^{-1}) followed by Vetiver (13.7 mg kg^{-1}).

Contrary to that based on the study conducted on three tropical grass land on phytoremediation potential of Cd, vetiver grass accumulated about 90mg/kg of Cd followed by *Imperata cylindrica* which accumulated about 76 mg/kg in dry weight basis (Ng, *et al* 2016) In other experiment where the common hyper accumulator plant i.e., *Thysanolaena maxima*, compared with *Vetiveria zizanioides (L.)* for the phytoremedation of lead contaminated soil. For instance, at higher concentration of lead contamination (10,000mg /kg of soil) the vetiver ecotype Kamphaeng Phet and *Thysanolaena maxima* accumulated about 6000mg/kg and 4600 mg/ kg of Pb in their dry biomass (Rotkittikhun, *et al* 2007).

On the other hand, the efficiency of vetiver in rehabilitating Pb and Cd contaminated land of the oil shale mine with low PH value(4.01) of Maoming Petro-Chemical Company, China was compared with other three plant species. Interestingly, after growing the plants for 6 months in the field, highest Pb concentration of 3.64 mg/kg were up taken by vetiver while St. Augustine grass accumulated the least amount (1.17 mg/kg). In contrast the bana grass found to collect about 0.384 mg/kg of Cd compared to vetiver which absorbed about 0.159mg/kg (Xia, 2004).

2.2. Plant Growth Response

The growth performances of vetiver in response to its use in the Phytoremediation of heavy metals contaminated field were found to be superior compared to other species. For instance, the growth of vetiver (*V. zizanoides*), Imperata (*I. cylindrical*) and Pennisetum (*P. purpureum*) were tested in different growth media thatare spiked with heavy metals like cadmium (Cd), lead (Pb), zinc (Zn) and copper (Cu) for 60 days. Among the three grasses no significant difference on the plant height of vetiver was observed between all treatments and the control while significant difference was observed for the other two grasses.

Generally considering the spike treatments the plant heights recorded for vetiver (Cd=73.81, Pb=72.33 cm, Zn=61.23cm and Cu=60 cm were the highest compared to Pennisetum (Cd=30,Pb=40 cm, Zn=32cm and Cu=48.7cm) and Imperata (Cd=33,Pb=29 cm, Zn=24cm and Cu=44.89 cm). Likewise, from different vetiver ecotypes grown in highly lead contaminated soil(toxic level) an average plant height of 35cm was obtained compared to the *Thysanolaena maxima* plant which grows only up to 24cm at this level of Pb concentration(Ng, *etal*2016; Rotkittikhun, *et al* 2007).

Shu *et al* 2002 tested the growth of vetiver with other three plants on Pb/Zn mine tailings using three treatments applied to the field. taking the average biomass production of the plants including the control vetiver produced the highest biomass of about 1315 g/m^2 followed by *P. notatum* with 575 g/m^2 and the lowest biomass was produced by *I. cylindraca* (368g/m^2) while *C. dactylon* produced 445 g/m^2. Similarly, about 30t/ha of vetiver biomass was produced from an area that is contaminated by Pb, Zn and Cd while about 6, 5 and 2.5 t/ha of biomasses were produced respectively, by *Viola baoshanensis, Sedum alfredii* and *Dianthus chinensis* grown on the same field(Zhuang, et al 2007).

2.3. Growth and Heavy Metal Accumulation Efficiency of Vetiver

Metal accumulating capacity and biomass production are the two major important factors that determine the phytoremediation efficiency of a plant. (McGrath and Zhao 2003). Particularly when it comes to non-hyper accumulator plant their growth rate and huge biomass production ability is very indispensable. As it is observed in the review paper, the concentration Pb, Zn as well as Cd were lower in the tissue of vetiver a non-accumulator plant when it is compared to the other hyper accumulator plant like *V.baoshanensis* and *S. alfredii.*

However, due to its high biomass production, vetiver could accumulated about 46.5kg of Pb, 144.9kg of Zn and 4kg of Cd per hectare of land which is significantly higher than *V.baoshanensis* and *S. alfredii* could accumulate. Similar observations were reported where the accumulation of Lead and copper were found to be highest in shoots vetiver compared to three hyperaccumulator grasses which has higher concentration of Pb and Cu in their shoots (Shu, et al 2003) Similar result was reported that the vetiver showed higher biomass production than *Cynodon dactylon* when grown mine tailings (Shu et al., 2002).

Several researches reported that vetiver grass has high level of tolerance to different kinds of heavy metals (DANH et al, 2009). Likewise, in this review it was seen that growth performance vetiver was not affected when it was grown in a soil spiked with Pb, Cd, ZN and Cu compared to the other species. In addition to that at high level of metal concentration like in the case of Pb at 10000 mg/kg the commonly known hyper accumulator showed low lead content in its tissue compared to the vetiver ecotype. This indicates the higher lead tolerance capacity of vetiver due to its adaptation potential to extreme conditions.

Similarly, in other research growing vetiver on a soil contaminated with lead at concentration of 5000mg and 4000mg /kg did not affect its growth performance (Chen et al 2004; Yang *et al.*, 2003). Generally, it was also reported that the vetiver was found to grow optimally in soils that are contaminated with Cd (60 mg kg^{-1}), Cu (1000 mg /kg) and Zn (2400 mg/kg) (Danh et al, 2009). In addition to that in this review once again it was proved that at low PH value of 4.00 the vetiver biomass production and Pb content was higher than bahia grass, St. Augustine grass, and bana grass. This indicates that vetiver can grow in high acidic environment.

3. Conclusion

According to the review it is found heavy metal contamination is one of the major threat for human as well as the ecosystem. its classical remediation technologies have been being time consuming costly and they are not environmentally friendly but the alternative option of using plants for rehabilitation of contaminated sites is proved to be eco friendly and cost effective. However, due to the inherent nature of the plants adaptation to different conditions and their growth characteristics the efficiency of phytoremediation varies among the commonly used heavy metal accumulator. However, the review presented that the vetiver grass due to its high biomass production, tolerance to high concentration of heavy metals and high capacity to survive under low PH compared to other plant was identified as the best plant for the phytoremediation contaminated areas.

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