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Application of Vetiver Grass Technology for Dump slope stabilization and Effluent Treatment – Case Studies

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Abstract - *Vetiver Grass (Vetiveria zizanioides, L. Nash) is native to Mysore of Karnataka in south India and is found throughout the tropic regions. But it is reported to grow satisfactorily in the temperate regions up to 420 latitudes (north) also (Greenfield, John C., 1993; World Bank, 1990). It is characterised by a deep root system, and its ability to withstand harsh environmental conditions like drought, fire incidents, frost, heavy metal toxicity, water logging etc. makes it a global tool for efficient soil stabiliser, crop conservator, soil ameliorator and remediator from heavy metal toxicity. It is also known for the aromatic and medicinal properties of its various parts. There is no wonder that the World bank took the initiative to establish the global Vetiver Network around the world for soil conservation. Developed countries like China and Australia are researching to discover and model the capacity of Vetiver to bring about a sustainable and economical solution namely Vetiver Grass Technology to many environmental problems. In this paper, the authors review the vivid application of Vetiver grass worldwide giving a glimpse of its recent uses in the Kusmunda opencast coalmine, Korba for dump slope stabilization and Bongoigaon Refinery, Assam in India. Vetiver showed positive results in the control of erosion at the dumps but is found somewhat ineffective to beat the harsh conditions. Whereas the application of Vetiver for effluent contaminated with oil for its treatment showed oil is trapped in roots. Moreover, the total dissolved solids (TDS) and total suspended solids (TSS) showed lower levels consistent with the roots and shoot growth rates of Vetiver grown in floats in eco-ponds at the refinery. Vetiver grass is also observed to uptake heavy metals such as Pb, Se, Co, Zn, Ni, Cu etc. Their concentrations are found to be more in the roots than in the shoots except for the Zn. Vetiver is also found to control eutrophication by up-taking macronutrients (NPK) in the test site.*

Key Words: Vetiver Grass. Uses of Vetiver Grass. Dump Slope Stabilization, Effluent Treatment

1. INTRODUCTION

The Vetiver grass (*Vetiveria zizanioides, L. Nash*) or Vetiver (hereinafter) is synonymic to *Chrysopogon zizanioides* (L.) Roberty sssssss to Panicoideae subfamily of the Poaceae family in Sorghina subtribe of the Andropogonae tribe (Berta and Camussso, 2002). It is commonly known as *Bala* in Hindi, *Abhaya, Amrinala, Bala* in Sanskrit, and *Khas Khas* in Bengali. It's a perennial grass with a lifespan of 1.5-2 years. It is an established phyto-stabilizer and soil erosion controller, grass system, being popularly used worldwide today. It is characterized by a long (sometimes up to 3.5 m) fibrous root system with morphological properties such as bulk shear and tensile strengths which aids in both the aspects of stability and erosion control. As per Grimshaw (1994), "*roots of trees and other vegetation provide a reinforcing effect to the soil through tensile resistance and frictional and adhesion properties*". It has tolerance to extreme conditions such as highly acidic, high salinity, water scarcity, insects, and high metal toxicity. It is known for its medicinal advantages and root oil. Thus, it has been a sustainable and economical environmental protection tool with manifold uses for society. Dalton et al., (1996) reported that Vetiver is both a xerophyte and a hydrophyte and not affected by either drought or flood once established. Literature reveals that vetiver grass is tolerant to frost, heat, sodic and saline conditions and can grow on a wide range of soil pH (3-11).

The Vetiver is native to Mysore of Karnataka in south India and is found throughout the tropic regions. But it is reported to grow satisfactorily in the temperate regions up to 42^0 latitudes (north) also (Greenfield, John C., 1993; World Bank, 1990). The advantageous physiological features of Vetiver include tolerance to adverse climatic conditions (drought, flood, heat waves, and frost, etc.), edaphic (Acidity, alkalinity, saline, Aluminum(Al), and Manganese(Mn) Toxicities, etc.), and high levels of heavy metals, such as Copper (Cu), Chromium (Cr), Lead (Pb), Mercury(Hg), Nickel(Ni), Selenium(Se) and Zinc(Zn) (Truong and Baker, 1998).

1.2 Erosion control by Vetiver hedgerows

Vetiver is capable of forming thick hedgerows (Fig. 1.1) when planted without significant spacing which is effective in reducing sheet erosion as shown in (Fig. 1.2). The raindrops impact upon the loose surface soil particles and make them dislodged which is then carried away by runoff to cause fatal sheet erosion Vetiver hedge resists the runoff (A) flow and reduces the kinetic energy of the suspended particle. The particle thereby settles down to form a silt sediment bed (B) retained by a Vetiver hedge. The runoff, (C) after silt deposition, flows across the Vetiver hedgerows at a slower rate and thus, has lesser erosion-causing potentials (Liu et al., 2014). The deep spongy root system withstands the hydrodynamics and soil movement caused by runoff and supports the stiff Vetiver shoot forming hedgerows.

Fig. -1.1: Vetiver hedges are formed when planted close together (after, Truong et al., 2008)

Fan et al. (2008) reported the fibrous roots found in Vetiver grass are advantageous in high moisture content during rainy conditions giving it higher shear resistance than those of trees and shrubs with tap roots. Soil conservation and moisture retention in has increased the productivity of crops of maize (Babola et al. 2003).

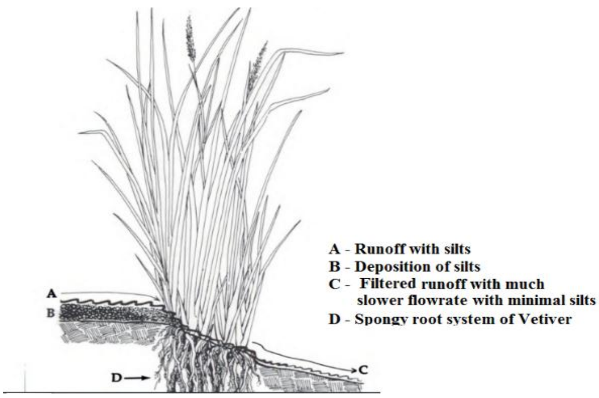

Fig.-1.2: The cross-section of the Vetiver plant (After, Greenfield, 1993)

2. APPLICATION OF THE VETIVER GRASS SYSTEM IN VARIOUS FIELDS

Various articles report the use and application of the Vetiver system to control various environmental problems such as wastewater treatment (Truong and Hart, 2001). The main purpose for developing the Vetiver system is to conserve soil and water, but it has also found its application in wastewater treatment. It has been developed from research and developments conducted in various countries for the last fifteen years and has been used in 40 countries with tropical and subtropical climates. This shows its worldwide application for environmental protection purposes. Their research work tried to: (1) develop a hygienic, practical, and economic method of disposing of effluents from small domestic sources, (2), quantify the effectiveness of the Vetiver System in reducing the nutrient load and volume of domestic and industrial effluents, and (3) calibrate Vetiver grass for application in computer modelling. Vetiver has been used for waste treatment in Thailand (Xia et al., 2000) and China (Kong et al., 2003)

2.1 Control of Eutrophication (Algal Growth) in Rivers and Dams

Zheng et al. (1998) mention the applications of the Vetiver System in China, which are grown in wetlands, or created for the treatment of excessive N and P (a potential cause for the eutrophication in water bodies), or grown in water hydroponically on floating platforms. P (mg/L) removal percentage is found greater than N (mg/L). About 99.3% of P removal and a maximum cumulative of 71.0 % of Total N removal is obtained between three to four weeks of plantation of Vetiver saplings.

2.2 Control of Agrochemical Pollution

Vetiver hedges planted in sugarcane farms in north Queensland are found to trap some nutrients, such as P and Ca, which are particulate bound whereas it has little effect on soluble nutrients such as N and K (Truong, 2000). Reduction of the P is found ranging from 26% to 69%, whereas, for the Ca such reduction by Vetiver Hedge, ranged from 51% to 56%. Cotton farms with such Vetiver hedge shows prevention of '*herbicides (diuron, trifluralin, prometryn, and fluometuron), pesticides [organochlorine (α, β and sulphate endosulfan) and organophosphate (chlorpyrifos, parathion, and profenofos)]' (Truong, 2000). 'Endosulfan' is a chlorinated hydrocarbon insecticide and acaricide of the cyclodiene subgroup which acts as a poison to a wide variety of insects and mites on contact*' (The extent toxicology network website (2016)). Endosulfan is banned in India to use as a pesticide. Thus, Vetiver could be an effective bioengineering tool for preventing the accumulation of these harmful organic matters in soils and it acts as a mobilizer for those pesticides.

2.3 Wetland plant

Vetiver growth is studied to be unaffected by some herbicides (Atrazine or Diuron up to 2000 μgL-1) when used in wetland treatments. On the contrary, the wetland plant, Phragmites Australis, suffers from these herbicides at given concentrations. Vetiver is found suitable for growth in wetland conditions and also tolerant to those herbicides at specified high-level concentrations (Cull et al.2000). It can reduce the flow velocity of the water and increase the sedimentations of sediment-bound heavy metals and can enhance the bed stability of such pollutants. It also stimulates microbial activities in the rhizosphere.

In these connections, it is noteworthy to mention that, in Thailand, it is reported that Vetiver could decontaminate agrochemicals and could prevent those accumulations in the crops. Some experiments also show Vetiver has the ability to uptake a significant amount of NPK, Ca, Mg, Pb, Cd, and Hg. The laboratory experiments exhibit that Vetiver could uptake Heavy metals. Thus, it is found suitable for wastewater treatment (Cull et al., 2000).

2.4 Effluent disposal

Vetiver is used to test its efficiency in the treatment of effluents from both domestic and industrial sources. In Brisbane (1995), Vetiver hedgerows are able to completely suck up the runoff of domestic effluent from a holiday camp and prevent the nearby lake from leaching of it to the lake shore. A similar application of reducing the volume effluent from a septic system, using 100 Vetiver plants in an area of less than 50 m^2, is shown experimentally at the Beelarong Community Farm in Brisbane, Australia.

2.5 Landfill Leachate Disposal

In Australia, leachate is treated with Vetiver grasses, and in a case study (Truong and Stone, 1996), it is found that leachate runoff is highly contaminated with Cadmium, Copper, Chromium, Zinc, and Lead. This is completely stopped by the Vetiver plant after one year of plantation in Brisbane, Queensland, Australia. Similarly, at Port Douglas, north Queensland, Vetiver is planted to check the leachates from the landfills (Truong and Hart, 2001). In India, the use of Vetiver for the reclamation of wastelands and for site recreation is also reported (Nikhil and Sunil, 2012; Ansari and Nikhil, 2014a, b; and Nikhil, 2014).

2.6 Phyto-remediation of Heavy Metals using Vetiver

Plants show different kinds of sensitivity to metal concentrations in soil. They vary in their response in a manner that some plants are sensitive to even low concentrations of some metals, whereas others show significant tolerance to fairly high metal concentrations in soil. Vetiver has been used for treating heavy metal contaminations in China (Wong et al., 1999; Wong M.H., 2003; Chen et al., 2004). Vetiver is reported to enhance the uptake of As, Zn, and Cu with a chelating agent (Chiu et. al, 2005) and with manure compost (Chiu et. al, 2006). It is found satisfactorily growing in lead-contaminated soil and up taking lead (Rotkittikhun et al., 2007). Its capability of tolerance produces hyperaccumulation of metals in Vetiver without any significant symptoms of toxicity in roots and shoots that it is extractable from plant shoots. This phenomenon is also known as 'Phyto-extraction' (Manoj et al., 2014). The hyperaccumulation of some metals in the plants has been proposed: '100 mg kg^{-1} for Cd, 1,000 $mgkg^{-1}$ for Ni, Cu, Co, and Pb, and 10,000 mg kg^{-1} for Zn and Mn' (Angin et al., 2008).

2.7 Other Miscellaneous uses of Vetiver grass

The Vetiver newsletter by Newsletter of the Vetiver Network (1996) provides proven uses of Vetiver such as:

(a) As Natural Resources - (1) on-farm soil and water conservation (2) groundwater recharge (3) wasteland rehabilitation (4) gully control (5) drainage stabilization (6) wind erosion control (7) Floodplain stabilization (8) Inhibitor to the movement of excess soil chemicals (9) river bank stabilization (10) permanent boundary and demarcation (11) in construction and engineering as a resource for - Embankment and cut stabilization (12) Construction site stabilization and (13) mine dump stabilization and rehabilitation

(b) In Pollution Control - (1) tolerance to high levels of toxic metals (2) inhibitor to the movement of toxic metals (understudy) (3) municipal and industrial waste dump stabilization (3) excess herbicide and pesticide clean-up (understudy) (4) clean-up of brackish water fishery waste (understudy) (5) wastewater clean-up and in (c) various economic uses like livestock mulch, fodder, crop yield enhancement, medicinal, aromatic oil, thatch, compost, fuel, natural herbicides and pesticides (under study), handicrafts, and mushroom substrate.

3. APPLICATIONS OF VETIVER IN INDIA

(a) Traditional and Tribal uses

The Vetiver (*Vetiveria zizanioides L. Nash*) grass grows in a 'versatile situation' having finer branched rootlets. A number of uses of the Vetiver system are reported in India, such as 'oil is extracted from it for perfumes', dump and slope stabilization in surface mines, soil and water conservation in agricultural lands etc. The dry roots of Vetiver are used for making fans, cushions, mats, and other fancy handicrafts which are aromatic in wet conditions (Alam and Kumar, 2005). Vetiver grass is also used as medicine traditionally by many tribes in India. It is also the primary material for making various household goods. The uses of Vetiver by Indian tribes are as tabulated below as per Rao and Suseela (2000).

Table-1: Traditional uses of Vetiver grass and its constituents as medicine by Indian tribes (Rao and Suseela, 2000)

Tribe	Plant	Ailment
Santhals	*Root decoction*	*As cooling in high fever, inflammation, sexual*
Tribes of	*Root*	*Malarial fever*
South Indian	*Leaf paste*	*Rheumatism and sprain*
Tribes of M.	*Root juice*	*Anthelmintic*
Most tribes	*Vetiver oil*	*Stimulant, diaphoretic and*
Lodhas	*Root paste*	*Headache, fever, Ayurvedic preparation "Brihat Kasturi", and "Bhairava Rasa" for fever, diarrhoea,*
South Indian tribes	*Root and stem juice*	*Boil, burn, epilepsy, scorpion sting, snakebite,*
Oraons	*Root ash*	*Acidity*

(b) Dump Slope Stabilization in opencast mines

Hengchaovanich and Nilaweera (1998) report a strong and positive relationship between Vetiver roots to slope Stabilisation. In India, some remarkable initiatives to use Vetiver grass for slope stabilization in Indian mines were adopted. In this connection, Zoda East Iron mines (22°0′11″N, 85°26′28″E) in Odisha state were introduced with Vetiver for spoil dump slope stabilization successfully (Banerjee et al., 2016). The Vetiver plants have shown the character of tolerating toxic metal concentration with "*reduced chlorophyll content fewer numbers of tillers, reduced chlorophyll content, upregulation of antioxidant enzymes, and increased proline content*" (Mukherjee et al., 2015). Similarly, Vetiver grass is also introduced in the Noamundi Iron Mines of Tata Steel company in Jharkhand successfully. The Vetiver grass could grow 1.5 - 2m in height in less than six months and sustain the summer season.

A test project of Vetiver grass plantation is launched in 2017-18 for dump slope stabilization and environmental protection at Dump-13 and slopes at railway siding at the Kusmunda Opencast Project of south eastern coalfields limited (SECL) during monsoon and post-monsoon seasons by the method of slip multiplication. The plant spacing was adopted as 30 cm (Plant to Plant) X 100 cm (Interrow). The

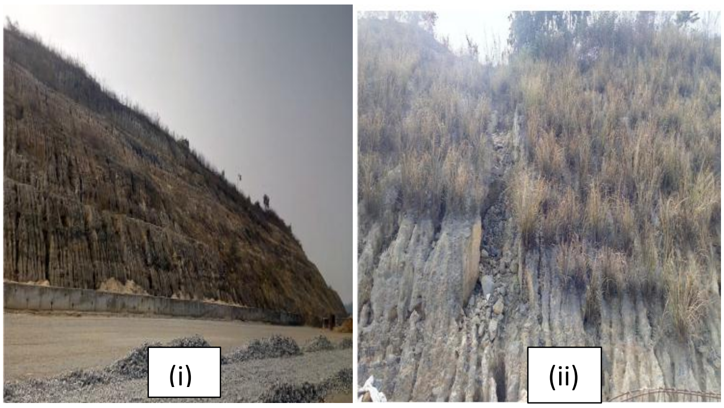

Fig.-2: The view of the Sides at the Railway Siding before the plantation of Vetiver (i) and after Vetiver has grown on its slope (ii) (after, Pathak K., 2019)

Vetiver slips have been grown with the garden soil of a nursery that has been established for the purpose of the supply of the slips. The photographic presentation of Vetiver grass growth in Dump 13 and in Railway siding is shown in Fig. (2) & Fig. (3).

It is evident from the photographs that Vetiver grass could thrive with sustenance protecting the slopes from erosions such as sheet erosion and reel erosion. But the spacing of Vetiver row to row could not produce a stiff hedge, limiting its ability to control erosion. This could be a reason for the presence of erosional features such as reels or gullies, though less severe, as observed across the slope with Vetiver grass.

It will be noteworthy that Vetiver grass could not compete with wilderness after it is left unchecked for a long in natural conditions. Many patches of Vetiver die in the shades of trees planted and are replaced by spreading wild 'Deenanath Grass' *(Pennisetum pedicellatum)* sown for making green cover before the plantation of Vetiver on the slopes of Dump 13.

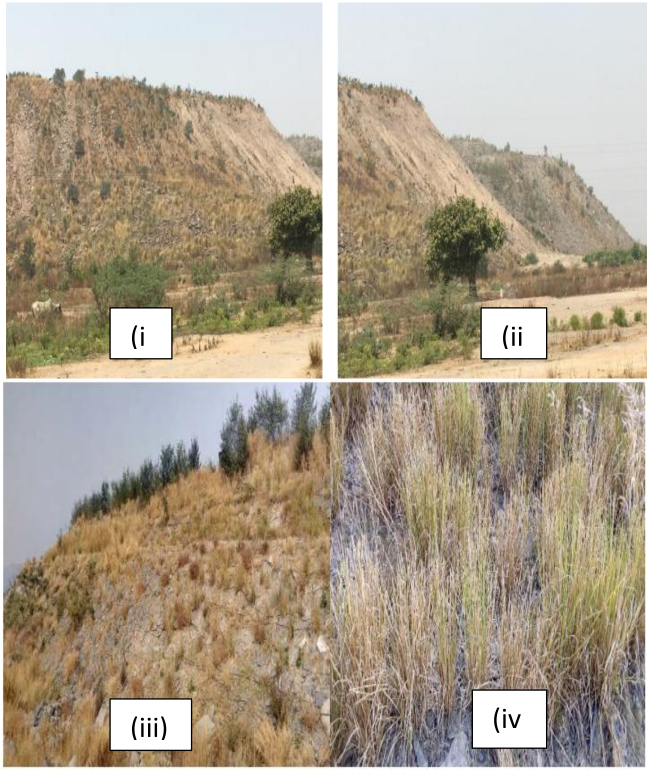

Fig.-3: The view of the Dump-13 before the plantation of Vetiver (i) & (ii) and after Vetiver has grown on its slope (iii) & (iv) (after, Pathak K., 2019).

(c) *Effluent Treatment of Oil Refinery*

In the year 2013-14, Vetiver grass is tested for the treatment of effluent, especially, total dissolved solids (TDS), total suspended solids (TSS) treatment in the hydroponic system at Bongoigaon Refinery, Indian Oil Corporation Limited (IOCL), Assam. The Vetiver grass is grown in the eco-pond's inlet and inside the eco-pond contaminated with oil, tied-in floats constructed of the bamboo framework as shown in Fig. (4). The initial root length and shoot length of Vetiver kept was 30cm and 200cm respectively for multiplication. The average humidity varied from 60% to 88% in eight weeks period of study. The temperature varied from 27^{0}C to 33^{0}C with a fluctuating but rising trend where the temperature dips about 2^{0}C in the 2nd -3rd week and in the 5th -6th week out of the 8th weeks of the study.

It is encouraging to witness that the Vetiver survives in effluent contaminated with the oil. It is observed that Vetiver slips could grow their roots about 162.85 cm in six months (an increase of 81.57%) and their shoots about 654.64 (an increase of 76.59%). The rate of root and shoot growth is faster during the first 14 days, which becomes steady after 21 to 30 days and decreases later.

It is seen that Vetiver roots grow longer with effluents and oil trapping them. The TDS values initially increase after which they decrease sharply. The initial increase in TDS values may be due to the presence of contaminants in water which release various components into water. However, with time the contaminants may get removed by the Vetiver plants resulting in a decrease in the TDS values.

Fig. 4: The response of Vetivers on trapped oil- (i) Eco Pond inlet, (ii) Pond with puree, (iii) Vetiver roots trapping oils (iv) float in eco-pond (after, Pathak K., 2013)

The root and shoot samples were taken and analysed using AAS for heavy metals uptakes by Vetiver (Pathak K., 2014). The resulting concentrations of the macronutrient (NPK) and heavy metals in the root and shoot are shown in Table (2) and compared graphically in Fig. 5(i) and (ii).

As shown in the abovementioned figures, Vetiver can reduce eutrophication by gulping macronutrients NPK by a range of 293.3 – 15586 ppm. Their concentrations are found to be more in the shoots (368 – 15586 ppm) than in the roots (293.3 – 6123 ppm) of Vetiver. Potassium (K) is found to be the highest in concentration, whereas, Phosphorus is the lowest nutrient among the NPK in these tests.

Table-2: The concentrations of the macronutrients and heavy metals found in the root and shoot of Vetiver

Particulars	**Concentration in Vetiver's roots (ppm)**	**Concentration in Vetiver's shoots (ppm)**
Nitrogen (N)	742	1106
Phosphorous (P)	293.3	368
Potassium (K)	6123	15586
Cobalt, Co	4.9	ND*
Nickel, Ni	4.3	3.8
Lead, Pb	42.6	4.6
Selenium, Se	884.16	381
Copper, Cu	14.1	6.8
Zink, Zn	11.16	67.6

*Not Applicable

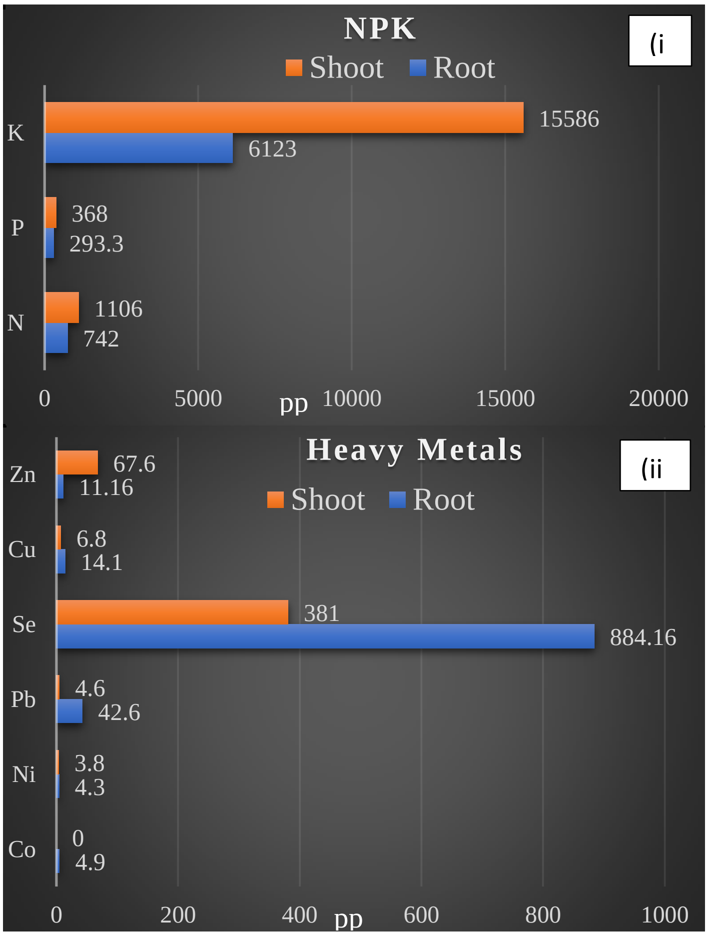

Fig. 5: The concentration of NPK (i) and Heavy Metals (ii) as found in the root and shoot parts of Vetiver

On the contrary, the concentration of heavy metals (Co, Ni, Pb, Se, Cu and Zn) is found to be magnificently lesser (3.8 – 67.6 ppm) than those of NPK. All of them, except the Zn, are found greater in roots than in shoots of Vetiver. Among the heavy metals, selenium is absorbed unimaginably higher (381 ppm and 884.16 ppm in the root and shoot of Vetiver respectively) due to contamination.

4. CONCLUSIONS

The potential of Vetiver grass to enunciate remedies to various environmental problems is reviewed and found to be well-established globally. Its recent uses in Indian industries viz. Kusmunda opencast coal mine for dump slope stabilization and Bongoigaon Refinery for effluent treatment are found effective. The Vetiver showed promising results in both cases as per the observation. It grows to form thick bush grass with a height of up to 2-2.5m as reported in various studies. But, its lack of self-sustenance in harsh conditions and its inability in combatting weeds such as Deenanath Grass *(Pennisetum pedicellatum)* shows that it requires caring for its efficient working. It might be because of the sterile cultivar The Vetiver is found to uptake heavy metals to considerable levels such as Co, Se, Ni, Pb, Cu and Zn as per the study conducted at Bongoigaon Refinery for the same. Further, it is found to uptake macronutrients (NPK) and limit eutrophic algal bloom in eco-pond there. The concentrations of these nutrients are found to be more in the shoot than in the roots. Potassium (P) is found to be the most consumed macronutrient among (NPK).

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