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Full Length Research Article

Phytoremediation for Sustainable Environment in Polluted Land

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Abstract

Pollution is a major concern in this century, the leaders of all countries are begun to discuss to find out solution for sustainable environment. Industrialization is the main reason of polluting the environment especially with toxic heavy metals. We cannot shutdown the industries because we consider for both protection of environment as well as preparation of development. This work is aimed to design the sustainable environment for the polluted land. Normally the pollutants are somewhat mitigated by certain plants; that technology is called "Phytoremediation". By using this Phytoremediation technology, the hyperaccumulator (the plant which is tolerate to grow in the more toxic level of metals and absorb the metal and somehow alleviates toxicity level in the environment) is selected to design a pollution free environment. The hyperaccumulator species such as *Amaranthus spinosus* L. and *Amaranthus virdis* L. are grown in the metal (As, Ni, Cu, Ba, Zn, Ti and Co) polluted areas and find out their ability to alleviate toxin levels in the environment by calculating the following factors, Accumulation Factor (AF), Translocation Factor (TF) and Mobility Index (MI). The metal level in the soil also observed before and after the cultivation of hyperaccumulator. The result reveals that the hyperaccumulators remove the pollutants in the environment and make our environment sans pollution. It was concluded that, the new design of cultivating hyperaccmulator in the polluted area surely provides sustainable environment.

***Key words*:** Sustainable environment, Hyperaccumulator, Metal stress, Accumulation factor, Translocation factor

Environment is the surroundings, in which all living organisms are live and functions together. Since last century our environment has been exploiting through revolution of industries and day by day our fertile soil system affected worse by the contaminants and toxins which release from various industries. Environmental pollution of heavy metals poses major havoc to the environment. Various industries are continuously discharging their wastes to soil, water and air even rapid growing agriculture leads to the usage of chemical fertilizers and pesticide [1]. A substantial increase of pollution level in the environment threatens natural ecosystem and also human health: the quality of soil, water and air decreases. Whenever, the polluted water and metal contaminated agricultural products are consumed by human, the toxins are transferred to human and it would pose a severe health risk [2]. Heavy metals induces cellular damages in the plants, some of heavy metals copper, magnesium, nickel, zinc, cobalt, chromium etc. are essential to plant growth and metabolism only at their bioavailable form but it excesses then, it becomes potential toxic to the plants and it eventually biomagnified in agricultural products too [3]. Heavy metals are non-biodegradable and causes deleterious effect to plants; damaging DNA, denaturation of cell structure and membrane results in programmed cell death [4].

The industrial city Sivakasi is well known for the hub of firecrackers manufacturing units/factories. Nearly 950 fireworks and 620 matchbox manufacturing units, huge amount of chemicals have been used during the manufacturing of crackers including many heavy metals each and every day. Generally, all the fireworks are placed amidst of agricultural land; all factories diabolically dumped or burned unloaded chemical mixture in the evening. Particulate matter in atmosphere and metal toxicity in the soil have been accruing due to this improper disposal activity of these industries. This scrapheap slowly spreading in agricultural land eventually makes verdant land into barren. This disposal activity is inalienable from fireworks; it impaired the crops grown in that area. It is impossible to stop the cracker manufacturing; the consideration is both the production of environment as well as preparation of development.

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The demonstration of fireworks is one of the important air and water pollution during the festival [5]. Bursting and burning of firecrackers induces lot of aerosol in the atmosphere, these aerosol reduces photosynthetically active radiation reaching the surface and also pose severe respiratory problems to human [6]. The recent research identifies that the seven metals (Mg, Al, K, Cu, Sr, Ba and Bi) are generally released during the bursting of firecrackers; their concentration is increases causes negative impact of the health of living organism in the environment [7]. These pollutants adversely impact on environmental biotic and abiotic components and contaminated all natural resources; various health issues are created, therefore there is an urgent need to control such toxins [8].

Currently, no proper effective technique has introduced to cub the metal pollution nip in the bud. But sustainable way of approach to control the heavy metal contamination of the environment is need of the hour, the Phytoremediation (the process of mitigate the metal pollution by plants) is best tool to combating the metal toxins in the environment [9]. Remediation of polluted land is profoundly important, Phytoremediation is a eco-friendly approach to mitigate pollutant and revegetate the metal polluted soil in cost effective way [10]. Some plant species are commonly grown in the scrapheap dump site; it may alleviate the toxicity level. Hyperaccumulator take up particularly high amount of toxic substances, usually a metal or metalloid in their shoot during normal growth and reproduction. The potential of hyperaccumulation is depends on the selection of the suitable plants. Normally *Amaranthus* species is employed in various metal polluted sites to mitigate toxins in the environment, it is good for remediating cadmium and lead [11], *Amaranthus hybridus* is potential to remediate brewery effluent and the author suggest. The mechanism of detoxification of plants growing in polluted areas should be explored [12], *Amaranthus mangostanus* L. is a potential hyperaccumulator for Cs and Sr contaminated soil it translocate and sequestered the toxins [13], *Amaranthus dubius* is used to remove the contaminants in semi-arid soil [14] and *A. retroflexus* is a hyper accumulator plants for Cr, Cd, Cu, and Ni [15]. Therefore, the selected plant species of *Amaranthaceae* family is sustained to grow in firecracker polluted sites.

This study is aimed to create new design for fireworks polluted sites, and also analyse toxic metals present in the scrapheap of firework to find out the potential of common native hyper accumulative plant *Amaranthus spinosus* L. and *Amaranthus virdis* L. to accumulate and remediate heavy metals from the environment.

MATERIALS AND METHODS

Sample collection

The fireworks' scrapheap was collected from three different firecracker's manufacturing units, Sivakasi. Triplicate set of scrapheap soil was prepared for detect various metal concentration. Seeds were collected from widely grown *Amaranthus spinosus* L. and *Amaranthus virdis* L. in dump sites. Soil samples were air dried at room temperature for two weeks, crushed and pulverised to pass through 2mm sieve. The metal concentration of soil samples was analyzed [16].

Soil preparation and plant culture

For experimental design five uniform triplicate set of earthen pot was selected, in each pot four kg of experimental soil is taken. Uniform mixture of red, black and sandy soil in 1:1:1 ratio was taken for control. The remaining set, site soil and control soil were mixed in following ratio; 25% (1:3), 50% (2:2), 75% (3:1), 100% (4:0).

Widely collected seeds of *Amaranthus spinosus* L. and *Amaranthus virdis* L. were surface sterilized with 0.1% of mercuric chloride and sown in all experimental pots uniformly; treated with distilled water.

After 65 days old *Amaranthus spinosus* L. and *Amaranthus virdis* L. were taken to measure metal concentration, each plant samples was analyzed [16]. Each sample was digested in a mixture of nitric acid and perchloric acid (10:1) the solution was centrifuges at 5000 rpm for 5 minutes, double filtered with Whatman filter paper No.1 and the collection were analyzed for metal concentration by Atomic Absorption Spectrometry (Model AA 6300).

Accumulation factor (AF)

The Accumulation Factor (AF) was considered to determine the quantity of heavy metals absorbed by the plant from soil. This is an index of the plant to accumulate a particular metal with respect to its concentration in the soil and is calculated using the formula [17]:

$$\text{Accumulation factor (AF)} = \frac{\text{Metal concentration in the tissue of whole plant}}{\text{initial concentration of metal in substrate (soil)}}$$

Translocation factor (TF)

To evaluate the potential of plant species for phytoextraction, the Translocation Factor (TF) was considered. This ratio is an indication of the ability of the plant to translocate metals from the roots to the aerial parts of the plant [18]. It is represented by the ratio:

$$\text{Translocation factor (TF)} = \frac{\text{Metal concentration in Stems+Leaves}}{\text{Metal concentration in Roots}}$$

Mobility index (MI)

Mobility index (MI) was considered to determine the biomobility and transport of heavy metals in different plant parts. The whole experiment was divided into three categories: Level 1 (Soil – Roots), Level 2 (Roots – Stems) and Level 3 (Stems – leaves) [19].

$$\text{Mobility index (MI)} = \frac{\text{Concentration of metal in the receiveing level}}{\text{Concentraion of metal in the source level}}$$

Statistical analysis

The data were reported as mean ± SE Statistical analysis (One way ANOVA – Tukey test) was done using the statistical package, origin – version 7.0.

RESULTS AND DISCUSSION

The metal concentration in the scrapheap of fireworks contaminated soil was analyzed and tabulated in the (Table 1).

Table 1 Metal concentration in scrapheap soil of fireworks industry

Name of the metals	Metal concentration in ppm g^{-1}
Arsenic (As)	357 ± 0.170
Nickel (Ni)	420 ± 0.118
Copper (Co)	718 ± 0.207
Barium (Br)	469 ± 0.185
Zinc (Zn)	292 ± 0.074
Titanium (Ti)	621 ± 0.068
Cobalt (Co)	389 ± 0.672

Values are an average of three observations. Mean ± SE

In this present study the fireworks' industry scrapheap contain heavy metals such as Arsenic (As), Nickel (Ni), Copper (Co), Barium (Br), Zinc (Zn), Titanium (Ti) and Cobalt (Co). among these seven heavy metals copper shows high amount 718 ppm gm^{-1} followed by titanium, barium and nickel, zinc show in least amount (292 ppm gm^{-1}).

Heavy metal concentration in Amaranthus spinosus L. and *Amaranthus virdis* L.

Accumulation factor (AF)

The Accumulation Factor (AF) was used to determine the quantity of heavy metals absorbed by the plant from soil. This is an index of the plant to accumulate a particular metal with respect to its concentration in the soil. The higher the accumulation factor the more suitable is the plant for phytoremediation.

To evaluate the heavy metal accumulation in the experimental plant tissue, the accumulation factor (AF) was calculated on the effect of fireworks' scrapheap dump soil with various heavy metals and tabulated in (Table 2-3). The accumulation factor of each metal in *Amaranthus spinosus* L. and *Amaranthus virdis* L. has been increasing while increase in soil metal concentration, among the seven metals arsenic has high accumulation factor for *Amaranthus spinosus* L. ranging from 1.763 to 1.927, in *Amaranthus virdis* L. zinc shows high accumulation factor even in 25% of metal contaminated soil.

Table 2 Accumulation factor of various metals in *Amaranthus spinosus* L.

Metals	Control	Test soil			
		25%	50%	75%	100%
Arsenic (As)	BDL	1.763 ± 0.249 a*	1.812 ± 0.194 a*	1.837 ± 0.034 a*	1.927 ± 0.108 a*
Nickel (Ni)	BDL	0.896 ± 0.375 a*	1.005 ± 0.243 a*	1.072 ± 0.093 a*	1.242 ± 0.076 a*
Copper (Co)	BDL	1.208 ± 0.249 a*	1.318 ± 0.156 a*	1.340 ± 0.168 a*	1.437 ± 0.027 a*
Barium (Br)	BDL	1.582 ± 0.106 a*	1.683 ± 0.275 a*	1.728 ± 0.384 a*	1.752 ± 0.021 a*
Zinc (Zn)	BDL	1.127 ± 0.116 a*	1.245 ± 0.069 a*	1.410 ± 0.137 a*	1.427 ± 0.124 a*
Titanium (Ti)	BDL	0.736 ± 0.082 a*	0.816 ± 0.059 a*	0.905 ± 0.138 a*	0.926 ± 0.174 a*
Cobalt (Co)	BDL	1.186 ± 0.048 a*	1.429 ± 0.137 a*	1.461 ± 0.007 a*	1.537 ± 0.079 a*

Values are an average of three observations. Mean ± SE, a – refers to value compared with control in various concentrations of metals, a* – refers to significant (P ≤ 0.05 – Turkey test). BDL – Below Detectable Level

Table 3 Accumulation factor of various metals in *Amaranthus viridis* L.

Metals	Control	Test soil			
		25%	50%	75%	100%
Arsenic (As)	BDL	1.293 ± 0.276 a*	1.429 ± 0.162 a*	1.447 ± 0.083 a*	1.453 ± 0.005 a*
Nickel (Ni)	BDL	0.742 ± 0.062 a*	0.984 ± 0.051 a*	1.092 ± 0.128 a*	1.103 ± 0.052 a*
Copper (Cu)	BDL	1.275 ± 0.072 a*	1.521 ± 0.076 a*	1.642 ± 0.173 a*	1.951 ± 0.012 a*
Barium (Br)	BDL	0.729 ± 0.009 a*	0.816 ± 0.063 a*	0.829 ± 0.050 a*	0.954 ± 0.034 a*
Zinc (Zn)	BDL	1.896 ± 0.375 a*	2.005 ± 0.243 a*	2.652 ± 0.093 a*	2.942 ± 0.076 a*
Titanium (Ti)	BDL	0.708 ± 0.249 a*	1.018 ± 0.156 a*	1.340 ± 0.168 a*	1.437 ± 0.027 a*
Cobalt (Co)	BDL	1.782 ± 0.106 a*	2.183 ± 0.275 a*	2.728 ± 0.384 a*	3.002 ± 0.021 a*

Values are an average of three observations. Mean ± SE, a – refers to value compared with control in various concentrations of metals, a* – refers to significant (P ≤ 0.05 – Turkey test). BDL – Below Detectable Level

The accumulation factor was varied in both the plants while grown in the concentration of soil and in control soil all the metals are below detectable level (BDL). In 100% of site soil concentration, the plant *Amaranthus spinosus* L. shows the highest accumulation factor for the metal arsenic (1.927) and barium (1.752). The plant *Amaranthus virdis* L. shows highest accumulation factor for the metal cobalt (3.002) and zinc (2.942).

Translocation factor (TF)

To evaluate the potential of plant species for phytoextraction, the Translocation Factor (TF) was calculated. This ratio is an indication of the ability of the plant to translocate metals from the roots to the aerial parts of the plant. Metals that are accumulated by the plants and largely stored in the roots of plants are indicated by TF values <1, with values greater including translocation to the aerial part of the plant. To find out the potential of *Amaranthus spinosus* L. and *Amaranthus virdis* L. for phytoextraction, the translocation factor (TF) was calculated on the effect of various concentration of firecrackers manufacturing waste dump soil and tabulated in (Table 4-5).

Table 4 Translocation factor of various metals in *Amaranthus spinosus* L.

Metals	Control	Test soil			
		25%	50%	75%	100%
Arsenic (As)	BDL	1.102 ± 0.285 a*	1.952 ± 0.850 a*	2.457 ± 0.601 a*	3.154 ± 0.092 a*
Nickel (Ni)	BDL	1.124 ± 0.642 a*	1.512 ± 0.472 a*	2.124 ± 0.008 a*	2.451 ± 0.102 a*
Copper (Cu)	BDL	1.279 ± 0.138 a*	1.541 ± 0.278 a*	2.425 ± 0.244 a*	2.806 ± 0.075 a*
Barium (Br)	BDL	2.411 ± 0.347 a*	3.050 ± 0.186 a*	4.217 ± 0.038 a*	4.752 ± 0.208 a*
Zinc (Zn)	BDL	1.523 ± 0.756 a*	1.961 ± 0.274 a*	2.861 ± 0.005 a*	3.254 ± 0.576 a*
Titanium (Ti)	BDL	1.674 ± 0.651 a*	2.014 ± 0.789 a*	3.174 ± 0.029 a*	3.856 ± 0.078 a*
Cobalt (Co)	BDL	1.163 ± 0.179 a*	1.952 ± 0.624 a*	2.730 ± 0.285 a*	3.021 ± 0.405 a*

Values are an average of three observations. Mean ± SE, a – refers to value compared with control in various concentrations of metals, a* – refers to significant (P ≤ 0.05 – Turkey test). BDL – Below Detectable Level

Table 5 Translocation factor of various metals in *Amaranthus viridis* L.

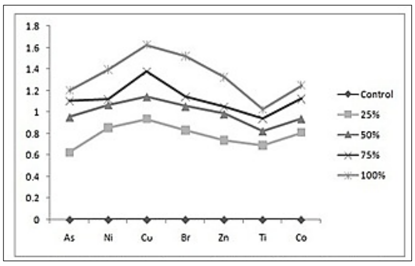
Metals	Control	Test soil			
		25%	50%	75%	100%
Arsenic (As)	BDL	1.001 ± 0.284 a*	1.082 ± 0.814 a*	2.052 ± 0.308 a*	2.750 ± 0.751 a*
Nickel (Ni)	BDL	1.127 ± 0.579 a*	1.427 ± 0.488 a*	2.158 ± 0.014 a*	2.856 ± 0.026 a*
Copper (Cu)	BDL	2.104 ± 0.109 a*	3.451 ± 0.825 a*	4.278 ± 0.175 a*	4.952 ± 0.106 a*
Barium (Br)	BDL	1.934 ± 0.086 a*	2.183 ± 0.242 a*	3.412 ± 0.624 a*	4.120 ± 0.737 a*
Zinc (Zn)	BDL	1.459 ± 0.138 a*	1.901 ± 0.278 a*	2.523 ± 0.244 a*	2.917 ± 0.075 a*
Titanium (Ti)	BDL	2.411 ± 0.347 a*	3.150 ± 0.186 a*	4.017 ± 0.038 a*	4.812 ± 0.208 a*
Cobalt (Co)	BDL	1.613 ± 0.756 a*	1.961 ± 0.274 a*	2.241 ± 0.005 a*	3.457 ± 0.576 a*

Values are an average of three observations. Mean ± SE, a – refers to value compared with control in various concentrations of metals, a* – refers to significant (P ≤ 0.05 – Turkey test). BDL – Below Detectable Level

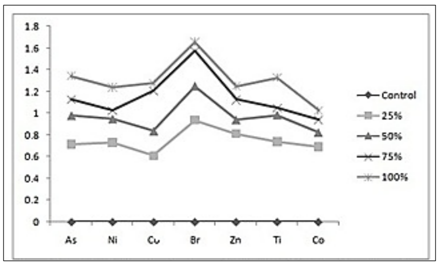
Mobility index (MI)

Mobility Index (MI) was used to determine the biomobility and transport of heavy metals in different plant parts. The whole experiment was divided into three categories: Level 1 (Soil – Roots), Level 2 (Roots – Stems) and Level 3 (Stems – Leaves).

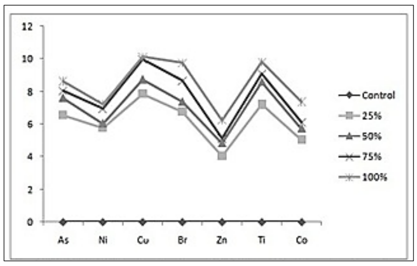
The transport of heavy metals from soil to leaf was found out through the mobility index (MI) of plants. The mobility index of various metals of scrapheap firework's soil treated *Amaranthus spinosus* L. and *Amaranthus virdis* L. were represented in the (Graph 1-6).



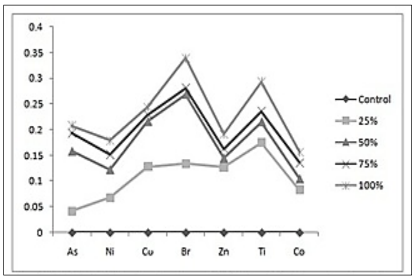
Graph 1 Mobility index level 1 (Soil to root) of various metals in *Amaranthus spinosus* L.



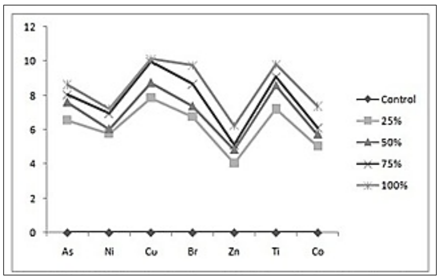
Graph 2 Mobility index level 1 (Soil to root) of various metals in *Amaranthus viridis* L.



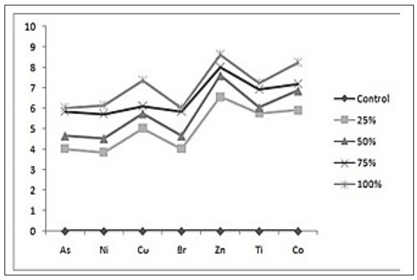
Graph 3 Mobility index level 2 (Root to stem) of various metals in *Amaranthus spinosus* L.



Graph 4 Mobility index level 2 (Root to stem) of various metals in *Amaranthus viridis* L.



Graph 5 Mobility index level 3 (Stem to leaf) of various metals in *Amaranthus spinosus* L.



Graph 6 Mobility index level 3 (Stem to leaf) of various metals in *Amaranthus viridis* L.

The transport of heavy metals from soil to leaf was found out through the mobility index (MI) of plants. The mobility index of various metals of scrapheap firework's soil treated *Amaranthus spinosus* L. and *Amaranthus virdis* L. were represented in the (Graph 1-6). It was divided into three levels. Level 1- Soil to Root; Level 2- Root to Stem and Level 3- Stem to Leaf. In Level 1, the mobility index was increased in all the metals while increasing concentration of soil, there is no mobility of metal in control soil. In 25% of site soil concentration *Amaranthus spinosus* L. and *Amaranthus virdis* L. has high mobility index in the metal copper and barium respectively. The metal lithium, arsenic and nickel shows lowest mobility.

In level 2 (Root to Stem), the metal zinc in *Amaranthus spinosus* L. and barium in *Amaranthus virdis* L. contain higher mobility than other metals. In level 3 (stem to leaf), mobility index was nil in control soil. In four concentrated site soil treatment in *Amaranthus spinosus* L. and *Amaranthus virdis* L. shows the mobility index of the metals is in the following levels: Ti>Cu>Ba>As>Ni>Co>Zn and Zn>Co>Ti>Cu>Ni>As>Ba respectively.

The firecrackers' manufacturing waste materials cause major havoc to the agriculturist, naturally toxins of firecrackers cause severe damage to human and the environment [6]. The biological activity of soil is very sensitive to heavy metals [8]. The area of ecosystem in and around this firecracker manufacturing unit was sorely damaged due to their scrapheap has high heavy metal concentration. Plants used for phytoremediation have a potential to accumulate heavy metals from contaminated soil and make them less harmful due to their well-developed root system and production of large biomass under adverse soil condition and able to grow in the high toxin polluted sites [20]. Phytoextraction is a soil remediation technology that makes use of the plants to extract metals from contaminated soils. Since plants can only accumulate metals in the labile fraction of the soil, the success of phytoextraction would be restricted by the unavailability of soil metals. Generally, at high contaminant concentrations in soil or water, plants are able to metabolize these harmful elements. However, some plants can survive and even grow well when they accumulate high concentration of toxic elements, as is the case of the hyperaccumulator plants. So, the present study the hyper accumulator *Amaranthus spinosus* L. and *Amaranthus virdis* L. were grown in the scrapheap dump site soil shown the great accumulation and translocation potential of heavy metals.

Amaranthus spinosus L. and *Amaranthus virdis* L. is a high biomass producing plants, leaves have the maximum accumulation of toxins among all crops [21]. The accumulation factor and translocation factor of all the seven metals show a gradual increase in *Amaranthus spinosus* L. and *Amaranthus virdis* L. with increasing concentration of soil contaminants, but in control soil both the factors were below the detectable level the same findings were observed in *Amaranthus hybridus* plant of [12]. The higher accumulation factor was varied in metal to metal in each level of soil concentrations, the mode of translocation varies from metal to metal; it shows few metals are accumulated by plant fast in lower concentration but in higher concentration the same metals make the retardant of plant growth and also the plant root block the accumulation, it shows the declining trend of metals accumulation factor in high concentrated soil [15]. However the accumulation factor of copper and aluminium is high in 100% contaminated soil; these metals chelated fast and accumulated in the plants [11].

If the accumulation factor (AF) and translocation factor (TF) values are above one, the plant is suitable for Phytoremediation [17]. In the present investigation, accumulation factor (AF) and translocation factor (TF) values are above one, in *Amaranthus spinosus* L. and *Amaranthus virdis* L. suggesting that it is best suited for phytoextraction of fireworks pollutants. The highest translocation factor 4.952 in 100% contaminated soil for copper shows the plant transfer more Cu pollutants than others in the scrapheap soil. The high translocation factor in all metals revels that it mitigates fireworks' pollutants and make the environment harmless to the agriculture [18]. The more translocation factor of metals shows the plant tolerance mechanism have involved neutralizing toxic elements and reach to the cytoplasm, i.e. metabolic processes and cell membrane were protected against damage [19].

The mobility index showed the mobilizing and transferring metals from one part to other part of the plants. Generally, the mobility index was very high in level 3 for phytoextracting plants due to their large biomass production, in this present study correlated with the findings of [16]. The low mobility index in level 2 reveals that metals are not stored in the stem, the plant stem immediately transfer the toxic ions to the leaves. The metal barium and copper shows high mobility index in level 1 in both plant, it indicates these toxic ions were either phytoextracted or phytostabilized by *Amaranthus spinosus* L. and *Amaranthus virdis* L. Ti, Cu and Br have high mobility index in level 3 in *Amaranthus spinosus* L. and Zn, Ti and Cu have high mobility in *Amaranthus virdis* L. and it confirmed that the Ti and Zn are stored in the *Amaranthus spinosus* L. and *Amaranthus virdis* L. leaves. The present study indicating the moderate rate of mobility of metals form soil to roots, higher mobility rate in stem to leaves, and low from roots to stem.

The aim of phytoremediation is not only mitigate the soil from the pollution but also restore the contaminated area for ecosystem balance and betterment of agricultural activities. The based on the result obtained from the translocation, accumulation factor and mobility index, the hyperaccumulator plant *Amaranthus spinosus* L. and *Amaranthus virdis* L. are suitable to remediate fireworks' scrapheap dump sites, restore the agricultural activities again and maintain the ecological balance.

CONCLUSION

It is a new designing land with hyperaccumulator to mitigate the pollution. The firecracker manufacturing units are inexorably polluting the environment, damaging the agricultural crops and even participate in climate change in this area. The Phytoremediation with native plants is a new cost-effective technology that is needed to alleviate the pollution in the land and give relief of farmer's apprehension. In the present findings of accumulation factor (AF), translocation factor (TF) and mobility index (MI) in *Amaranthus spinosus* L. and *Amaranthus virdis* L. indicates it is best suited for remediating firecracker polluted sites. Their high translocation factors of various metals is more than 1, so the plant is hyperaccumulator. Mobility index in various levels shows that *Amaranthus spinosus* L. and *Amaranthus virdis* L. is greatly mobilize the metals from soil and store in the leaves, and reduce their toxicity through biochemical mechanism. It is strongly concludes that the hyperaccumulator *Amaranthus spinosus* L. and *Amaranthus virdis* L. mitigate the fire crackers' pollution.

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