Agricultural land irrigated with high concentration of arsenic

Chapter 8

〖Removing Arsenic from Agricultural Land〗

The concentration of arsenic in soil varies that depends on: a) agricultural land (with or without irrigation, pesticide, fertilizer contaminated with arsenic), b) domestic garden, c) use of timber, d) mining area, and e) volcanic area. Irrigation of agricultural land with arsenic contaminated water shows high concentration of arsenic in soil. Country wise data of arsenic concentrations in soil are shown in Table 8.1. Average arsenic level in soil of Bangladesh is below 10 mg/kg, there is evidence that this value may exceed 80 mg/kg in places where arsenic-contaminated groundwater water is used for irrigation (Huq, 2008). In the past, numerous arsenical pesticides were used widely and, arsenic concentrations of 200-2,500 mg/kg occurred in the soil of orchards. Generally low amount of arsenic is present in the soil used for gardening. Sometimes the use of wood preservative containing arsenic may release arsenic from the wood of the house and contaminate the surrounding soil by releasing arsenic. On the other hand, the soil near the volcanic area and mining is highly contaminated with arsenic. The levels of 100-2,500 mg/kg have been found in the vicinity of copper smelters.

Table 8.1 *Arsenic contents in the soil of various countries.*

Country	**Amount of arsenic (mg/kg)**	
	Mean	**Range**
Argentina	5	0.8-22
Bangladesh	22.1	9-28
China	11.2	0.01-626
India (West Bengal)		10-196
Japan	11	0.4-70
Italy	20	1.8-60
Mexico	14	2-40
United States	7.5	1-20

(Mandal and Suzuki, 2002)

The regulatory limit established by the UK is set at 10 mg/kg for domestic gardens and at 40 mg/kg for parks, playing fields, and open spaces (O'Neil, 1990). On the other hand, much tighter guidelines of 0.80 mg/kg for residential and 3.7 mg/kg for non-residential have been established in Florida, USA (Tonner-Navarro et al., 1988).

Speciation study shows that two most common arsenic in soil are the inorganic forms As^{V} and As^{III}. Organic arsenic includes MMA^{V} and DMA^{V}.

Therefore, it is important to remove arsenic from the soil of agricultural land. However, the arsenic level in plant is more correlated with the water arsenic than with the soil arsenic. There are several methods by which we can reduce the soil arsenic contents. These are: a) phytoremediation, b) use of cow-dung, and c) earthworm.

8.1 Phytoremediation

Phytoremediation (phyto = plant and remediation = correct evil) is an emerging technology that uses various plants to degrade, extract, or immobilize contaminants from soil and water. The term is relatively new, coined in 1991.

Advantages: Phytoremediation offers an environmentally-friendly and cost-effective method to remove arsenic from the contaminated soil. This type of plant is fast growing, has high biomass, be easy to harvest, and must tolerate and accumulate high concentration of arsenic.

Disadvantages: Plants are slow-growing with a small biomass and shallow root system. Plant biomass must be harvested and removed, followed by arsenic reclamation or proper disposal of the biomass. Arsenic may have a phytotoxic effect.

Pentavalent arsenic might be taken up by plants because it is similar to the plant nutrient phosphate. Poplars are grown in soil containing an average of 1250 mg/kg arsenic (Pierzynski et al., 1994).

A number of plants are suggested to be useful. These are *Pteris vittata* *(*Chinese brake fern) (Figure 8.1), *Pityrogramma calomelanos*, *Mimosa pudica*, *Melastoma malabrathricum*, *Nephrodium molle* (Figure 8.2) (Ma et al., 2001; Alkorta et al., 2004).

P. vittata can remove more than 95% of the soil arsenic (Doucleff & Terry, 2002) (Figure 8.3), whereas the removal by *Nephrodium molle*is about 68% (Hossain et al., 2006). *Pteris vittata* may hyperaccumulate arsenic to extremely high concentrations, up to 23,000 μg arsenic/g, in its shoots (fronds) (Ma et al., 2001).

Figure 8.1 *The fern Pteris vittata.*

Figure 8.2 *Pityrogramma calomelanos (A), Mimosa pudica (B), Melastoma malabrathricum (C), Nephrodium molle (D) can accumulate arsenic from the soil.*

This process does not result in the disappearance of the arsenic. During phytoremediation, the arsenic moves from the soil to the fern fronds. It is then easy to harvest the fern fronds and further concentrate the arsenic in a safer location (Figure 8.4). Sometimes remediation processes result in complete destruction of the contaminant, as when microorganisms degrade polyaromatic hydrocarbons completely to carbon dioxide and water.

Colocasia antiquorum (arum), *Tagetes patula* (marigold) and *Ipomoea aquatic* (Kangkong) are also effective in removing arsenic from soil (Figure 8.5). Green and blue-green algae were found to hyperaccumulate arsenic from soil (Huq, 2008).

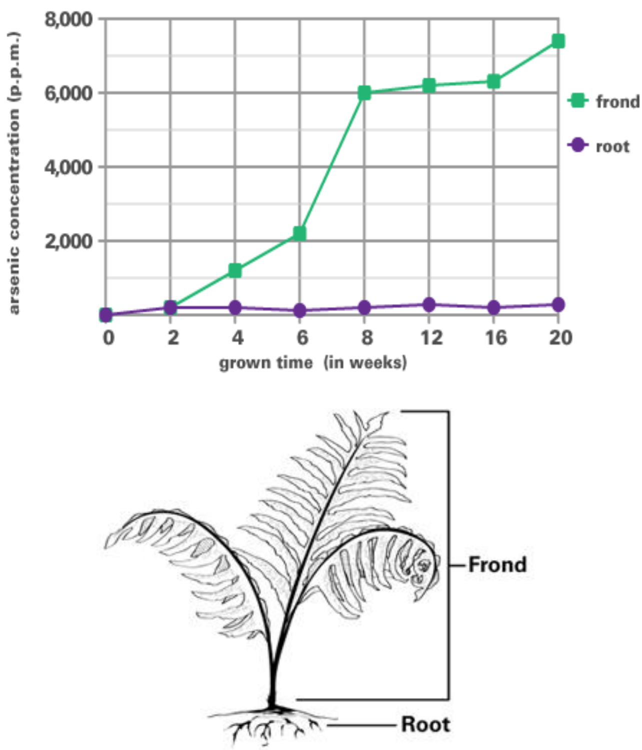

Figure 8.3 *Arsenic concentrations in fern Pteris vittata during growth in soil containing arsenic.*

Step 1
Fern *Pteris vittata* grown in soil contaminated with arsenic
→
Step 2
Harvest contaminated biomass
→
Pre-treatment
Compaction, combustion, composting
→
Final disposal
Burning or Landfill

Figure 8.4 *Steps to disposal of arsenic in the fern Pteris vittata.*

Figure 8.5 *(A) Colocassia antiquorum (arum), (B) Ipomoea aquatic (Kangkong) and (C) Tagetes patula (Marigold) can be used to remove arsenic from arsenic contaminated soil.*

It is an excellent idea of cultivating ferns together with rice plants that could compete effectively in accumulating arsenic, thereby reducing the amount of arsenic reaching the rice plants (Tan et al., 2010).

8.2 Cow-dung

A method of arsenic remediation sludge should be mixed with cow-dung so as to form methylate arsenic which then no longer poses a risk (Rahman et al., 2013). The study was conducted in the laboratory under controlled condition and is yet to be tested in the field.

8.3 Earthworm

The common earthworm, *Eisenia fetida*, could also become a useful tool directly for remediation of arsenic present in landfill soil and demonstrated an efficiency of 42 to 72% in approximately two weeks for arsenic removal (Figure 8.6). Earthworm could offer an inexpensive and effective bioremediation alternative to complex and costly industrial cleanup methods. Arsenic resistant earthworm *Lumbricus rubellus* and *Dendrodrillus rubidus* can accumulate arsenic from soil up to 877 mg/kg earthworm (Button et al., 2009). *L. rubellus* is found to inhabit arsenic-rich soils that contains up to 34,000 mg arsenic/kg dry soil weight (Langdon et al., 2001). XAS analysis of *L. rubellus* suggests that 30% of As^{III} is coordinated with sulfurs, suggesting binding to metallothionein (Langdon et al., 2002). Metallothionein is a thiol-rich (approximately 30% of its amino acid sequence), low molecular weight (approximately 6000 Da), metal-binding protein that is present in abundant in the liver and kidneys of mammals. Its biosynthesis can be induced by steroids, hormones, cytotoxic agents, and a wide range of metals, including As^{III} (Garrett et al., 2001).

Figure 8.6 *Varieties of earthworm (A) Eisenia fetida, (B) Lumbricus rubellus and (C) Dendrodrillus rubidus that can be used to remove arsenic from arsenic contaminated soil.*

8.4 Questions to be Raised

1. Can we remove arsenic from the filter sludge by the earthworm?

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