Abstract

This research was conducted in order to (a) to determine and select the most effective method for reduction of heavy metals from contaminated highland soil and (b) to evaluate appropriate method to handle heavy metal-contaminated plant that was used for extraction of heavy metals from agricultural highland area. For the first objective, three experiments were conducted, (1) selection of high arsenic-accumulating plant, (2) screening of effective microorganism for arsenic remediation and (3) determination of the appropriate method for reduction of arsenic-contaminated highland soil. The first experiment was carried out in vegetable growing greenhouse at Mae Tho village, Hot district, Chiang Mai province where the high concentration of arsenic (32.03 mg/kg) in soil has been reported. The experimental design was a randomized complete block (RCB) with 7 treatments. Sunflower *(Helianthus annuus)*, cowpea *(Vigna unguiculata* L.), nugget marigold *(Tagetes erecta* L.), field corn *(Zea mays* Linn.), Chinese cabbage *(Brassica pekinensis)*, coriander *(Coriandrum sativum* L.) and ferns *(Selliguea heterocarpa)* were used as the arsenic extracting plants. The second experiment was carried out at the laboratory of soil microbiology, Department of Plant Science and Soil Science, Faculty of Agriculture, Chiang Mai University. The two soil samples having different levels of arsenic were collected from greenhouse A1 (As = 32.03 mg/kg) and greenhouse A30 (As = 30.97 mg/kg) located in Mae Tho Royal Project Development Center, Hot District, Chiang Mai Province used in this experiment. Complete randomized design was conducted with three bacterial isolates, Ars. 8, Ars. 19 and Ars. 29 and three replications. Each tested bacterial isolate was inoculated to limed and unlimed soil at the rate 10^8 cfu/100 g. Uninoculated soil was used as control treatment. The third experiment was carried out at the same place as the first experiment. The experiment design was a RCB with 4 treatments and 4 replications. Three methods for arsenic remediation including phytoremediation by using field corn bioremediation by using Ars. 19 isolate bacteria and bioremediation using Ars. 19 isolate bacteria in combination with phytoremediation by using field corn were tested. No inoculation of Ars. 19 isolate bacteria and unplanted plot was used as control treatment. After arsenic remediation by selected methods was completed, Chinese cabbage, a commercial cash crop in highland area, was planted in each plot. At harvest stage, total arsenic content in root and shoot of Chinese cabbage was analyzed, then the efficiency of arsenic remediation method was evaluated.

For the second objective, the phytoremediation by-product obtained from the third experiment (field corn residues) were dried and milled to reduce biomass. Then powder of field corn residues was mixed well with cement (1:3 w/w) and moisturized for granule making. The product was packed in a column and leaching test was performed to evaluate the risk to environment.

The result showed that field corn had highest arsenic accumulation (266 µg/plant) followed by sunflowers (165 µg/plant), Chinese cabbage (109 µg/plant), nugget marigold (105 µg/plant), ferns (18 µg/plant), coriander (11 µg/plant) and cowpea (8 µmg/plant). Each plant species accumulated arsenic in different organs. The highest accumulation plant organs was root. The maximum of arsenic accumulation was found in the root of field corn at 3.66 mg/kg. However arsenic in coriander was accumulated the maximum at shoot (3.31 mg/kg). Evaluation of the effectiveness of three selected bacterial isolates; Ars. 8, Ars. 19 and Ars. 29 in reducing arsenic contamination in two soil samples was performed under laboratory conditions. The results indicated that liming could enhance the effectiveness of the microbes to reduce soil arsenic and the Ars. 29 isolate bacteria showed the highest effectiveness in arsenic reduction, therefore, this isolate was selected for the field experiment.

When field corn and Ars. 29 isolate bacteria were used in combination to treat the arsenic-contaminated soil, followed by growing Chinese cabbage to test the efficiency of the treatments, it was found that inoculation of Ars. 29 isolate bacteria to soil reduced arsenic uptake by Chinese cabbage significantly. Arsenic content in the edible above ground part of Chinese cabbage was 22.0 mg/kg, while the control treatment was 0.32 mg/kg.

In a study on methods to eradicate plant materials which were used to absorb arsenic in soil for highland agriculture, contaminated samples were dried, milled and compacted in order to reduce weight and volume of the samples. Then the power of field corn residue was mixed well with cement powder (1:3 w/w) and moisturized for granule making. Results from the study did not show the contamination of arsenic in the solution that was leached through cement granules which enwrapped the arsenic-contaminated plant samples. This suggested that when arsenic-contaminated plant samples were solidified with cement powder, arsenic could be retained without being released to the environment.

In conclusion, field corn had highest arsenic removal ability (2.66 g/rai), followed by sunflowers (2.12 g/rai) and nugget marigold (1.05 g/rai). In other words, the soil inoculation with Ars. 29 bacterial isolate incorporated with soil pH improvement by liming material tended to reduce arsenic content in arsenic-contamination soil. However, arsenic remediation by those methods did not reduce arsenic contaminated in soil. The arsenic concentration in soil was still in the high level (28.61-29.18 mg/kg). Moreover, arsenic contaminated in Chinese cabbage planted after arsenic remediation was detected, however, inoculation of Ars. 29 isolate bacteria to soil reduced arsenic uptake by Chinese cabbage significantly. In addition, mixing dried powder of phytoremediation by-product with cement (1:3 w/w) was the proper method for preventing the release of arsenic to environment.

Even though phytoremediation and bioremediation seem to be suitable methods for arsenic remediation in contaminated highland soil, however, a risk from application of arsenic-contaminated input such as manure, chemical fertilizer and pesticide should be considered. Therefore, to prevent the arsenic contamination problem, arsenic content in the input should be analyzed before being introduced to farmland.