Remediation of Arsenic Contaminated in Coal Ash Dumping Site using *Arachis pintoi* Krap. & Greg.

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Abstract**—**Coal ash (CA) is the hazardous waste produced from coal thermal power plant for electricity generation. The CA contains heavy metals which pose impact to human health and environment and can spread over causing air, water and soil pollution. Phytoremediation is the attractive method for cleaning up contaminated sites because of cost effective, aesthetic advantages and friendly to environment. This study investigated the ability and potential of *Arachis pintoi* Krap. & Greg. in remediation**.** The plants were grown in soil mixed with 25% 50% 75% and 100% CA. The height of plant growing for 90 days was increased. Accumulation of As was found in root tissue higher than upper parts and remediated up to 11.92%. It clearly showed that the plant had capability to grow and potential to remove As from coal ash dumping site.

Keywords**—** Arsenic, Coal ash, Remediation

I. Introduction

THE main product from the combustion of coal to generate electricity power is coal ash (CA). They are including bottom ash (BA) and fly ash (FA), while FA constitutes 85% - 90% of the overall ash. It has gray color, fine particle size about 0.01-100 µm. The material has a specific gravity between 1.7 - 2.4 BA constitutes about 10% - 15% of the overall ash, has an appearance similar to dark gray or black colors, particles are granule which up to 10 mm in diameter and specific gravity has between 2.1-2.7 [1].

In Thailand, BA are produced 1,500,000 ton/year and 3,000,000 ton/year for FA [2]. Due to the coal ash have fine particle size, therefore they can spread to long distance in the atmosphere causing air pollution and contaminate in soil and water. In addition, the CA is consist of macro elements and micro elements such as Zn, Cu, B, Co and Mo etc. [3] that can effect to environment and human health.

The positive effect of CA is due to essential elements content which help improve soil texture and promote plant growth. The percentage of germination in three plants (blue gemma, western wheatgrass and fourwing saltbush) which were cultivated in soil amended with BA have been increased as well as high growth rate [4]. The addition of 8 ton/acre BA in peanut farm was found percentage of yield up to 65% after harvested [5]. In the other hand, the study of FA contaminated with As at 3.4 mg/kg in Lucern bean tissue was reported toxic to sheep [6]. In case of Boron (B) above rate 30 mg/kg were considered impact to growth rate of *Eremochloa ophiuroides* Hack. decrease [7].

Phytoremediation is technique using plants to reduce, remove, degrade or immobilize environmental toxins such as heavy metals, trace elements, organic compounds and radioactive compounds. The term ‘‘phytoremediation’’ is a combination of two words from Greek is phyto (meaning plant) and Latin is remedium that meaning to correct or remove an evil [8]. Phytoremediation has numerous benefits such as able to work with organic and inorganic compounds, applied to both in-situ and ex-situ remediation, easy to implement and maintain, cost effective. Moreover, it’s friendly to the environment and aesthetically pleasing [9]. The investigation potential of *Vigna radiata* L., leguminous family plants was shown able to grow and resist in 100% FA medium [10]. The different species, *Sesbania cannabina* L. has also shown the potential to grow and accumulate metals in the decreasing order Fe, Mn, Zn, Cu, Pb and Ni [11]. The accumulation of heavy metals from 25% FA in *Phaseolus vulgaris* L. tissues was found highly metals Fe Mn Ni Cu and Co, respectively, in root tissue and Zn Pb and Cd, respectively, in shoot tissue [12].

Several documentations focus on leguminous family plants, the *Arachis pintoi* Krap. & Greg. was selected in this study. It is identified in Legumminous family and has not been reported in phytoremediation. It is a native plant of Central Brazil, an English name is Pinto peanut and Thua lisong tao for Thai name [13]. It is creeping plant and short lifespan which is appropriated to use in this study **(**Fig.1).

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Fig. 1 *Arachis pintoi* Krap. & Greg (Thua lisong tao)

The objectives this study were to investigate the ability and potential of *Arachis pintoi* Krap. & Greg. to remove Arsenic (As) in CA dumping site and evaluate the potential of plants for remediation.

II. Materials And Methods

A. Physical and chemical properties analysis

The soil samples and CA were analyzed for pH, electrical conductivity (EC), organic matter, cation exchange capacity (CEC) and content of As by using Inductively Couple Plasma (ICP) [12].

B. Experimental setup

The seedlings were planted in 12 in diameter pots containing soil and different amendments with 25% 50% 75% and 100% CA for 90 days [11]. All treatments were done outdoor at the same environmental conditions. The plant samples were measured the height and content of As after planting on 15, 30, 60 and 90 days to test the ability and tolerant in contaminated soil. After 90 days, the soil samples were analyzed for As remained in soil.

C. As accumulation in plant tissues and remaining soil.

After certain period, the plant were harvested, separated into root, shoot and leaves. All parts of plants were extracted with Nitric and Hyper choric acid ratio 3:1 by volume [18]. The solution were filtrated with Whatman paper No. 40 and analyzed the content of As in plant tissues [10].

D. Evaluation potential of plant.

The results of As accumulation in plant tissues were evaluated the phytoremediation capacity from Transfer factor (TF) and Bioaccumulation factor (BF) to study potential of plants for phytoremediation.

III. Result And Discussion

A. Physical and chemical properties of soil and CA

The soil samples and CA were analyzed for their physical and chemical characteristics and content of As. The results were shown in Table 1. Soil texture was loam. The pH of soil was 6.8 and CA was 9.48. The pH of soil was quite neutral which optimum to support of plant growth [14] while pH of CA was alkaline. CEC were 23.54 cmol/kg in soil and 13.40 cmol/kg in CA. Soil had high organic matter and clay minerals causing high CEC due to their large surface areas to exchange the cations [15].

Table I
Physical And Chemical Characteristics And Content Of As In Soil And CA

Parameters	Soil	CA
Sand (%)	50.50	-
Silt (%)	37.70	-
Clay (%)	11.80	-
pH	6.80	9.48
Organic matter (%)	11.57	-
CEC (cmol/kg)	23.54	13.40
EC (ds/m)	1.54	2.38
As (mg/kg)	6.14	22.40

B. Growth performance of plant.

The plant height was increased in all treatments after planting periods (15 30 60 and 90 days) that showing the ability of plant to survive in CA and soil mixed with different amount of CA (Fig.2). In 100% CA, plant growth was better than other treatments. The results were well agree with the seed germination of barley, Sudan grass, ryegrass, alfalfa and canola which were able to germinate on growth media containing more than 40% of FA and highest at 100% of FA [16]. This result was demonstrated that CA enhanced the plant growth according to the content of nutrients such as Ca, Mg, K, Mo, Zn and S which were essential to growth and development of plant [17].

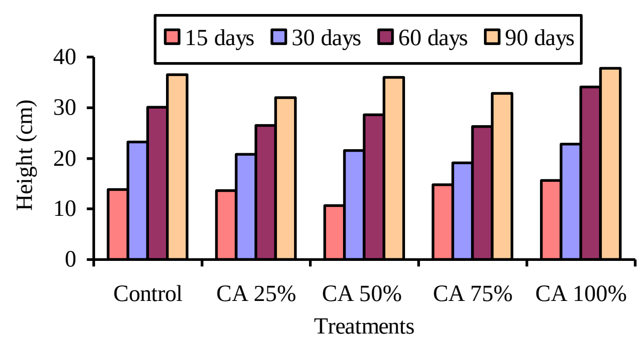

Fig.2 The height of *Arachis pintoi* Krap. & Greg. grown in soil mixed with CA

C. Accumulation As in plant tissues

After 90 days, the total accumulation of As in plant tissues were found in the decreasing order of root, leaf and shoot tissues (Fig.3) which was agree with Cu translocation from FA in *Sesbania cannabina* L. tissues [2]. The accumulation heavy metals in legume plants *Vicia faba* L. were Cu, Ni and Cr with concentration of 5 10 20 and 30 mg/kg and accumulated in root tissues than upper parts significantly [18]. In addition, phytoremediation potential of fern (*Thelypteris dentate* L.) after 30 day of planting in soil contaminated with As at 31 mg/kg was more accumulated in root tissue than another parts of plant tissues [19]. The metal accumulation was restricted to the root part showing the ability of metal to less translocation. It could be explained by the calculated value of BF and TF of plant after remediation.

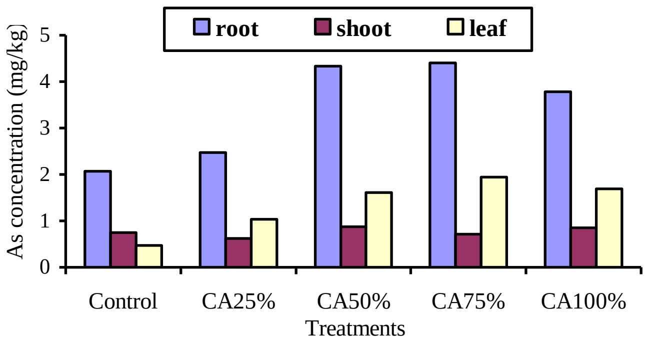

Fig.3 Total accumulation As (mg/kg) in root, shoot and leaf tissues of *Arachis pintoi* Krap. & Greg. after 90 days of planting

D. As remained in the soil mixed with CA

The As remained in soil mixed with CA after certain period of times were found decreased in all of treatments (Table 2). Conversely, the control treatment was slightly increased which might be due to the heterogeneous properties of soil samples. The results were indicated that plant can uptake metal from soil and be able to grow in soil contaminated with As from CA. In the 100% CA treatment, the plant could remediate As up to 11.92% after planting for 90 days.

TABLE II
THE AMOUNT OF AS REMAINING IN SOIL SAMPLES

Treatments	Days				
	0	15	30	60	90
Control	6.14	7.83	5.86	5.00	6.25
CA 25%	9.72	10.89	12.37	13.68	9.52
CA 50%	13.3	13.09	15.66	14.46	11.87
CA 75%	16.88	16.18	16.44	16.51	15.41
CA 100%	20.47	19.65	19.86	20.01	18.73

E. Evaluation the potential of plant in remediation

The potential of plant in remediation could be evaluated from the value of Bioaccumulation factor (BF) and Translocation factor (TF). The BF is defined as the ratio between the metal concentration in the plant tissue per that in the soil (1). The BF value is used to evaluate bioavailability for heavy metals accumulation in plants. The plant has BF value more than 1 is evaluated for heavy metal accumulation efficiency in plants and called Hyperaccumutor [20].

$$\text{Bioaccumulation factor (BF)} = \frac{\text{C plant}}{\text{C soil}} \quad (1)$$

The BF values of root, leaf and shoot tissues were shown in Table 3, showing the ability of root was more efficient to accumulate As than other parts.

TABLE III
BIOACCUMULATION FACTOR (BF) OF AS IN PARTS OF PLANT TISSUES

Treatments	BF values		
	root	shoot	leaf
Control	1.29	0.42	0.52
CA 25%	1.98	0.21	0.65
CA 50%	2.19	0.16	045
CA 75%	1.45	0.15	0.34
CA 100%	1.26	0.13	0.26

TF is defined as the ratio of the metal concentration in upper parts to above part (2) which is used to evaluate the effectiveness of plant in translocating metal from above ground to shoot and leaf [21].

$$\text{Translocation factor (TF)} = \frac{\text{C upper part}}{\text{C above part}} \quad (2)$$

The TF values of *Arachis pintoi* Krap. & Greg. were shown in Table 4. The TF were found highest in root followed by leaf and shoot. Therefore, the root of plant was able to uptake As from soil and translocate to leaf more efficient than shoot.

TABLE IV
TRANSLOCATION FACTOR (TF) OF AS IN PARTS OF PLANT TISSUES

Treatments	TF values		
	root	shoot	leaf
Control	1.35	0.48	1.94
CA 25%	2.52	0.30	1.42
CA 50%	2.42	0.23	1.10
CA 75%	1.90	0.31	1.24
CA 100%	1.35	0.36	0.81

IV. CONCLUSIONS

Arachis pintoi Krap. & Greg. was able to survive when it was planted in CA and had ability to remediate As in soil contaminated with heavy metals from CA dumping site. Furthermore, it showed the ability to accumulate As and translocate it to the upper parts. However, the metal accumulation in plant depended on types of metals and the bioavailability of metals to plants as well as the characteristics of each plant species. Further recommendation are to use this plant in the contaminated site and try to study another kind of plants that have capability to remediate heavy metals contaminated site.

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