The effect of fly ash application to Acacia growth and heavy metals leaching on peatland

I G M Subiksa¹, I W Suastika¹ and Husnain²

¹Indonesian Soil Research Institute, Bogor, Indonesia
²Indonesian Center for Agricultural Land Resources Research and Development, Bogor, Indonesia

E-mail: igm_subiksa@yahoo.co.id

Abstract. Research was focused on the effect of fly ash application on peatland at Lalang Kabung Village, Pelalawan Regency, Riau. The research objectives were to compare the effect of 3 types of fly-ash to the growth of Acacia crassicarpa and to investigate the potential on heavy metal pollution in groundwater of peatlands. The study was conducted using a randomized block design with 8 combined treatments with the type and rate of fly ash. Groundwater quality was monitored from a piezometer installed among 4 acacia trees. The results showed that the application of all 3 types fly ash significantly affect to acacia plant growth as indicated by the increased of stem diameter and plant height. Biomass fly-ash was better compared to coal and mixed fly-ash. The higher rate of fly-ash resulted on the better acacia growth. The results of water quality measurement taken from piezometer showed that there were 5 types of heavy metals detected in groundwater namely Pb, Co, Ni, Mo and Zn, but the concentration was still below the regulation threshold. There was no significant difference in heavy metal content among treatments both with and without fly-ash application.

1. Introduction
Fly ash is waste product of coal fired power plant. Fly ash and bottom ash classified as hazardous waste material category two as stated in government regulation No. 101/2014 which is utilization permit required. However, the government continues to encourage the use of fly ash through the Reduce, Reuse and Recycle (3R) mechanism [1] because fly ash production will increase due to the increasing number of coals fired power plant. Fly ash and bottom ash production from coal fired power plant in Indonesia attained 4.38 million tons in 2015 and predicted become 8.31 million tons in 2019 [2]. Large quantity of fly-ash produced by the coal fired power plant needs large area for landfill, and it is become source of pollution on both of air and water. Therefore, utilization must be encouraged so that it does not cause more serious environmental impact. In addition, utilization of fly ash for productive purposes will indirectly increase the efficiency of power plant operation and reduce environmental impacts due to massive landfilling. In Japan, JCEC [3] reported that fly ash and bottom ash can be used as fertilizer or soil amendment especially for acid soil. It is also used as raw material in fertilizer industry to produce potassium silicate fertilizer.

Fly ash is captured by mechanical separators, electrostatic precipitators, or bag fillers in the smokestacks to reduce air pollution [4]. Chemical composition of fly ash varies slightly depending upon the source of original coal where SiO₂ and Al₂O₃ account for 70 to 80% of total. Another mineral consisted of Fe₂O₃, CaO, MgO, K₂O, Na₂O and SO₃ [2]. Fly ash categorized into two classes namely F
and C class. The F class fly ash is normally generated due to combustion of anthracite or bituminous coal and C class is obtained by the burning of lignite or sub-bituminous coal combustion. C class fly ash possess CaO in excess (10 to 40%) while F class contains CaO less than 10% [5]. Due to higher CaO content, C class fly ash is potential to be utilized in agriculture sector as soil amendment. According to Melisa [6], physical and chemical properties of fly ash determined by kind of fuel source used in power plant. Power plant sometime use coal or biomas or mix of coal and biomas as source of fuel for the boiler. Therefore, fly ash quality in term of CaO content will be different one to another.

Fly ash has been reported containing environmental pollutants such as heavy metals [7]. There are many kinds of heavy metals, but some of them need special attention because they are easily contaminated soil and plants such as Hg, Pb, Cr, Co, Mn, As and Ni [8]. Environmental pollution according to law No. 32/2009 is the addition of living things, substances, energy, and/or other components into the environment by human activities in excess number of environmental quality standards. Conversely, fly ash is also contained Ca, Mg, K, Na, Fe, Cu, Zn and Mn, that could be used for soil amendment in reclamation of coal mined land [7, 6, 9]. Fly ash has alkaline nature that enable it to be used as an ameliorant for acid soils such as peatlands or acid upland. Therefore, the use of fly ash for any purpose that suspected will have an impact on the environment must be preceded by comprehensive testing. [10] showed that fly ash application as much as 5% of the soil can improve the growth of lyang-lyang’s seedlings.

The analysis results of FA showed that fly ash contain high silicon (Si). Although Si is not classified as an essential nutrient, but in plants, especially cereals crop, Si uptake is abundance so that it is called a beneficial element [11]. Rice plants require abundance of Si, where the plants absorb about 230 to 470 kg Si/ha or about twice N uptake [12,13]. Fly ash contains macro and micronutrients and thus promotes plant growth and ultimately improves the crop yield 10 to 40% [7]. Although the main function of Si in plants is not fully known, however, in rice plants it is proven to strengthen the rice straw so that they are not susceptible to pests and diseases attack [14]. Silicon is also important for strengthening stems cell wall. Plants deficient in Si will be susceptible to disease or lodging in the wind. Furthermore, [15] stated that the critical point of Si content in lowland rice is 300 mg SiO₂ kg⁻¹. However, several other researchers stated that Si was consider low if Si in soil was <600 ppm. The results of study by [16] predicted about 22.5% of intensified rice fields in West Java have low in Si status, mostly located in Karawang and Subang regencies.

Peatlands are soils that are formed from semi-decomposed plant debris under saturated water condition [17]. Peatland is marginal and fragile ecosystem due to its inherent soil properties, as a result their utilization creates significant environmental risks. However, peatlands are likely potential for agricultural development, especially for timber estate crop. The characteristics of peat soils are different from mineral soils in general. Peat and organic matter in general, have a high preference for metal cations, particularly polyvalent cations [18]. The polyvalent cations will form strong and stable coordination bond with organic matter. In this bond-forming condition, metal cations cannot be absorbed by plants and are not easily washed by or polluted the surrounding water. Fly ash may be useful as a fertilizer and ameliorant for acacia plants in peatlands because it is alkaline material and contains macro and micronutrients as well as polyvalent cations. However, its use needs to be studied more deeply, especially the possibility of heavy metal contamination in groundwater.

The objectives of this research were to assess the effect of direct application of fly ash in the field on the growth of acacia and to evaluate the possibility of heavy metals contamination in groundwater of peatland.

2. Materials and methods
The research was carried out on deep peatland at Lalong Kabung Village, Pelalawan Regency Riau Province in April to December 2018. The research site is the timber estate with the main tree Acacia crassicarpa. The materials needed consist of acacia seedling, 3 types of fly ash, fertilizers, chemical and equipment’s for laboratory analysis.
The study was done using randomized block design with 8 treatments and 4 replications as shown in table 1. Each treatment covered an area about 0.5 ha consist of 640 trees *Acacia crassicarpa*. The 9 weeks old of *Acacia crassicarpa* seedling were planted with planting distance 3 m x 2.5 m. The application of fly ash was done by spreading it on soil surface around tree trunk a week after planting. Fertilizers as blanket treatment consist of phosphate rock, KCl, Zinkcop and boron were applied just before planting as basal fertilizer. In each plot, 4 piezometers made from 2.5 inch PVC pipe were installed in 1.5 m depth in the middle of trees.

**Table 1.** Composition of 8 treatments of the research.

| Treatments   | Fly Ash (g tree⁻¹) | RP (g tree⁻¹) | KCl (g tree⁻¹) | Zinkcop (g tree⁻¹) | Boron (g tree⁻¹) |
|--------------|--------------------|---------------|----------------|--------------------|-----------------|
| Biomass-FA 1.5 | 1.5                | 75            | 40             | 10                 | 10              |
| Biomass-FA 3.0 | 3.0                | 75            | 40             | 10                 | 10              |
| Coal-FA 1.5   | 1.5                | 75            | 40             | 10                 | 10              |
| Coal-FA 3.0   | 3.0                | 75            | 40             | 10                 | 10              |
| Mix-FA 1.5    | 1.5                | 75            | 40             | 10                 | 10              |
| Mix-FA 3.0    | 3.0                | 75            | 40             | 10                 | 10              |
| Control       | 0                  | 75            | 40             | 10                 | 10              |
| Complete control | 0               | 0             | 0              | 0                  | 0               |

Remarks: Coal-FA= FA from 100% coal fuel; Biomass-FA= FA from 100% biomass fuel; Mix-FA= FA from mixture of coal 70% and biomass 30%; RP= phosphate rock.

Ground water samples taken from piezometer twice during 2 months namely 30 days after FA application (DAA) and 60 DAA. Chemical characteristics of fly ash to be analyses consist of pH, nutrient content (P, K, Ca, Mg, S, Na, Fe B, and Si), and heavy metals (Pb, Cd, Hg, As, Cr, Ni, Co, Sn, Hg, Se, Mo, Cu and Zn). Meanwhile the agronomic parameters to be observed consist of trees height and trees trunk diameter. The agronomic parameters observed 3 time at 30 DAA, 60 DAA and 210 DAA.

![Figure 1. Piezometer 1.5 m depth installed among 4 acacia trees.](image)

### 3. Results and discussion

#### 3.1. Peat soil characteristics

Peat soil in Lalang Kabung Village, Pelalawan Regency is belonged to ombrogenous peat and it does not support optimal plant growth naturally. The laboratory soil analysis result (table 2) showed that it is
extremely acid due to the abundance of organic acids. On the other hand, base cations content was very low where base saturation is only 2.2 to 2.7%. Soil cation exchange capacity (CEC) is very high, the status of N, P and K nutrients are classified as very low. With a low N content and a very high C/N ratio, the microbial activity should be very slow. Peat soil was also detected containing heavy metals Pb, Cd, Co, Cr, Ni, Ag and Mo in both layers of soil (table 3).

**Table 2.** Chemical characteristics of 2 composit soil sample taken from research site at Lalang Kabung Village, Pelalawan Regency Riau.

| No. | Parameters                                  | Soil Layer 0-25 cm depth | Soil Layer 25 – 50 cm depth |
|-----|--------------------------------------------|--------------------------|-----------------------------|
| 1   | pH : H2O                                   | 3.5                      | 3.3                         |
|     | KCl                                        | 3.2                      | 3.0                         |
| 2   | Organic matter:                            |                          |                             |
|     | Organic C (%)                              | 58.5                     | 44.6                        |
|     | N (%)                                      | 1.12                     | 0.72                        |
|     | C/N                                        | 52                       | 62                          |
| 3   | Extractable HCl 25%:                       |                          |                             |
|     | P2O5 (mg100 g⁻¹)                           | 24                       | 11                          |
|     | K2O (mg100 g⁻¹)                            | 7                        | 5                           |
| 4   | P2O5 -Bray-I (ppm)                         | 22                       | 20                          |
| 5   | Exchangeable cations:                      |                          |                             |
|     | Ca (cmol(+),kg⁻¹)                          | 2.32                     | 1.79                        |
|     | Mg (cmol(+),kg⁻¹)                          | 2.11                     | 1.44                        |
|     | K (cmol(+),kg⁻¹)                           | 0.24                     | 0.11                        |
|     | Na (cmol(+),kg⁻¹)                          | 0.41                     | 0.41                        |
|     | Total (cmol(+),kg⁻¹)                       | 5.08                     | 3.75                        |
| 6   | Cation Exchange Capacity (cmol(+),kg⁻¹)    | 108                      | 116                         |
| 7   | Base Saturation (%)                        | 2.0                      | 2.0                         |

3.2. **Chemical characteristics of fly ash**

From an environmental aspect, the presence of heavy metals in fly ash needs to be studied more deeply. These heavy metals are mostly environmental pollutants. The 13 types of heavy metals content in 3 types of FA presented in table 4. Among these 13 types of heavy metals analyzed, the lead (Pb) is the most abundance in fly ash namely 268 ppm in coal FA, 91 ppm in biomass FA, and 142 ppm in mix FA. Zinc (Zn) and copper (Cu) are also in substantial concentration namely 115 ppm and 64 ppm, respectively, in coal FA, and 105 ppm and 78 ppm in biomass FA. The presence of those heavy metals in fly ash is originally come from raw material used as fuel in coal fired power plant. However, the presence of those heavy metals in fly ash is still categorized as safe to use because its concentration is still below the critical limit of the standardized quality. Meanwhile, Zn, Cu and Mo are belonging to micronutrients that are needed by plants. The other heavy metals are generally low or undetectable. In general, according to Ministry of Agriculture regulation (Permentan) No. 36/2018, all of heavy metals, especially Pb, Hg, Cd and As are still below the quality standard threshold required, so that it can be said that all three fly ash is classified as safe for use in agriculture and forestry crops.

Fly ash also contains nutrients needed by plants for their optimum growth. Laboratory analysis result of nutrients content in 3 types FA presented in table 5. Biomass-FA and mix-FA were classified as C class FA, meanwhile coal FA is classified as F class. It is due to CaO content >10% in biomass-FA and
mix-FA, whereas coal-FA has < 10% CaO content. Fly ash contains macro and micronutrients in various amounts according to the type of FA. Biomass-FA and mix-FA have higher P and K nutrient content compare to coal-FA. Silicon is the most abundance element in FA, where biomass-FA has higher Si compared to the others. In conclusion, based on their chemical characteristics, coal-FA, biomass-FA and mix-FA are likely belong to safe used as ameliorant in peatland or other soil types for agricultural or forestry development.

Table 3. Heavy metal content in 2 layers soil samples taken from Pelalawan Riau.

| No. | Heavy Metals | Heavy metals content (ppm) |
|-----|--------------|---------------------------|
|     |              | Soil Layer 0–25 cm depth | Soil Layer 25–50 cm depth |
| 1   | Lead (Pb)    | 1.1                       | 0.8                       |
| 2   | Cadmium (Cd) | 0.46                      | 0.1                       |
| 3   | Cobalt (Co)  | 1.57                      | 0.68                      |
| 4   | Nickel (Ni)  | 1.11                      | 0.40                      |
| 5   | Chromium (Cr)| 1.89                      | 1.37                      |
| 6   | Arsenic (As) | 0                         | 0                         |
| 7   | Mercury (Hg) | td                        | td                        |
| 8   | Silver (Ag)  | 0.30                      | 0.54                      |
| 9   | Tin (Sn)     | 0                         | 0                         |
| 10  | Molybdenum (Mo) | 1.5                     | 1.64                      |

Table 4. Heavy metal content in coal-FA, biomass-FA and mix-FA used in the research.

| No. | Heavy metals (ppm) | Unit | Coal FA 100% | Biomass FA 100% | Coal 70+Biomass 30 Mix FA |
|-----|---------------------|------|--------------|-----------------|--------------------------|
| 1   | Lead (Pb)           | ppm  | 268          | 91              | 142                      |
| 2   | Cadmium (Cd)        | ppm  | 8            | 5               | 3                        |
| 3   | Cobalt (Co)         | ppm  | 33           | 13              | 29                       |
| 4   | Nickel (Ni)         | ppm  | 33           | 8               | 17                       |
| 5   | Chromium (Cr)       | ppm  | 34           | 19              | 33                       |
| 6   | Arsenic (As)        | ppm  | Td           | Td              | Td                       |
| 7   | Mercury (Hg)        | ppm  | Td           | Td              | Td                       |
| 8   | Silver (Ag)         | ppm  | 4            | 3               | 1                        |
| 9   | Tin (Sn)            | ppm  | 14           | Td              | 14                       |
| 10  | Selenium (Se)       | ppm  | Td           | Td              | Td                       |
| 11  | Molybdenum (Mo)     | ppm  | Td           | 5               | Td                       |
| 12  | Copper (Cu)         | ppm  | 64           | 78              | 69                       |
| 13  | Zinc (Zn)           | ppm  | 115          | 105             | 78                       |

Remark: Td = not detected.

3.3. Heavy metals leaching
The average value of heavy metals concentration in groundwater is shown in table 6 and table 7. The results showed that only 6 of the 13 types of heavy metals were detected in groundwater namely Pb, Ni, Ag, Mo, Cu and Zn. Those 6 heavy metals measured in very low concentrations, far below the toxicity characteristic leaching procedure (TCLP) quality standard for waste category 2. There was no pattern of heavy metals concentration among treatments, even in the control treatment (no fly ash treatment), those 6 heavy metals were detected with higher concentration compare to fly ash treatment. This
indicates that there is no effect of fly ash application on the concentration of heavy metals that can pollute ground water on peatland.

The same pattern is also observed in ground water sample taken 60 days after FA application (DAA), even Cu was no longer detected since Cu has a strong bond with organic ligands. Concentration of those 5 heavy metals were far below the quality standard of TCLP stated in PP. 101/2014. The results of the second groundwater analysis confirm the results of the first analysis that fly ash treatment has no effect on the leaching of heavy metals which can pollute the ground water and the surrounding aquatic environment.

**Table 5.** Nutrients content of coal-FA, biomass-FA and mix-FA used in the research.

| No. | Parameters   | Unit | Coal-FA | Biomass-FA | Coal-Biomass70:30 Mix-FA |
|-----|--------------|------|---------|------------|-------------------------|
| 1.  | P₂O₅         | %    | 1.12    | 1.26       | 1.38                    |
| 2.  | K₂O          | %    | 1.40    | 4.63       | 2.24                    |
| 3.  | CaO          | %    | 5.74    | 17.53      | 20.04                   |
| 4.  | MgO          | %    | 0.79    | 1.33       | 0.78                    |
| 5.  | Na           | %    | 0.87    | 0.16       | 0.82                    |
| 6.  | S            | %    | 1.39    | 0.26       | 1.60                    |
| 7.  | Fe           | %    | 2.73    | 2.78       | 3.58                    |
| 8.  | B            | ppm  | 294     | 108        | 185                     |
| 9.  | Soluble Si   | %    | 2.24    | 2.14       | 4.06                    |
| 10. | Total Si     | %    | 66.26   | 81.55      | 66.68                   |
| 11. | Ash content  | %    | 95.39   | 98.29      | 92.25                   |
| 12. | Neutralizing capacity eq. CaCO₃ | % | 38.81 | 18.88 | 22.16 |

**Table 6a.** Heavy metals concentration in groundwater 1 month after fly ash applied.

| Treatments         | Pb | Cd | Co | Cr | Ni | As | Hg |
|--------------------|----|----|----|----|----|----|----|
| Biomass-FA 1.5     | 0.09 | 0.00 | td | td | 0.03 | td | td |
| Biomass-FA 3.0     | 0.07 | 0.00 | td | td | 0.03 | td | td |
| Coal-FA 1.5        | 0.17 | 0.00 | td | td | 0.05 | td | td |
| Coal-FA 3.0        | 0.07 | 0.00 | td | td | 0.05 | td | td |
| Mix-FA 1.5         | 0.00 | 0.00 | td | td | 0.05 | td | td |
| Mix-FA 3.0         | 0.00 | 0.00 | td | td | 0.07 | td | td |
| Control            | 0.12 | 0.00 | td | td | 0.06 | td | td |
| Complete control   | 0.20 | 0.00 | td | td | 0.07 | td | td |
| Standard water quality*) | 1.00 | 0.01 | 0.20 | 1.00 | - | 1.00 | 0.005 |

Remarks: td = not detected; *) Standard class IV water quality suitable for crops based on PP. 82/2001.

3.4. *Acacia trees growth*

Acacia plants are known to have high adaptability growing under whatever environmental conditions. Therefore, the acacia is often used as a pioneer crop in land rehabilitation. However, if these plants are grown in a better environment, acacia will respond with faster growth. The average of tree height and trunk diameter of acacia observed at 30 days after fly ash application (DAA), 60 DAA, and 210 DAA are shown in table 8.
### Table 6b. Heavy metals concentration in ground water taken 1 month after fly ash applied.

| Treatments          | Heavy metals concentration 30 DAA (ppm) |
|---------------------|----------------------------------------|
|                     | Sn | Ag | Se | Mo | Cu | Zn |
| Biomass-FA 1.5      | td | 0.01 | td | 0.47 | 0.02 | 0.12 |
| Biomass-FA 3.0      | td | 0.03 | td | 0.96 | 0.01 | 0.10 |
| Coal-FA 1.5         | td | 0.02 | td | 0.88 | 0.01 | 0.13 |
| Coal-FA 3.0         | td | 0.02 | td | 0.74 | 0.02 | 0.20 |
| Mix-FA 1.5          | td | 0.03 | td | 0.93 | 0.02 | 0.11 |
| Mix-FA 3.0          | td | 0.03 | td | 1.33 | 0.02 | 0.13 |
| Control             | td | 0.03 | td | 1.40 | 0.02 | 0.13 |
| Complete control    | td | 0.03 | td | 1.44 | 0.02 | 0.11 |
| Standard water quality*)| - | - | 0.05 | - | 0.20 | 2.00 |

Remarks: td = not detected; *) Standard class IV water quality suitable for crops based on PP. 82/2001.

### Table 7a. Heavy metals concentration in ground water 2 months after fly ash applied.

| Treatments          | Heavy metals concentration (ppm) |
|---------------------|----------------------------------|
|                     | Pb | Cd | Co | Cr | Ni | As | Hg |
| Biomass-FA 1.5      | 0.01 | td | 0.02 | td | 0 | td | td |
| Biomass-FA 3.0      | 0.02 | td | 0.01 | td | 0 | td | td |
| Coal-FA 1.5         | 0.04 | td | 0 | td | 0.01 | td | td |
| Coal-FA 3.0         | 0.07 | td | 0.01 | td | 0 | td | td |
| Mix-FA 1.5          | 0.04 | td | 0 | td | 0.01 | td | td |
| Mix-FA 3.0          | 0 | td | 0.01 | td | 0.03 | td | td |
| Control             | 0.05 | td | 0 | td | 0.01 | td | td |
| Complete control    | 0.04 | td | 0.01 | td | 0.02 | td | td |
| Standard water quality*)| 1.00 | 0.01 | 0.20 | 1.00 | - | 1.00 | 0.005 |

Remarks: td = not detected; *) Standard class IV water quality suitable for crops based on PP. 82/2001.

### Table 7b. Heavy metals concentration in ground water taken 2 months after fly ash applied.

| Treatments          | Heavy metals concentration (ppm) |
|---------------------|----------------------------------|
|                     | Sn | Ag | Se | Mo | Cu | Zn |
| Biomass-FA 1.5      | td | td | td | 1.87 | td | 0.04 |
| Biomass-FA 3.0      | td | td | td | 1.49 | td | 0.03 |
| Coal-FA 1.5         | td | td | td | 1.8 | td | 0.03 |
| Coal-FA 3.0         | td | td | td | 1.84 | td | 0.04 |
| Mix-FA 1.5          | td | td | td | 1.8 | td | 0.06 |
| Mix-FA 3.0          | td | td | td | 1.7 | td | 0.02 |
| Control             | td | td | td | 1.82 | td | 0.02 |
| Complete control    | td | td | td | 1.63 | td | 0.03 |
| Standard water quality*)| - | - | 0.05 | - | 0.20 | 2.00 |

Remarks: td = not detected; *) Standard class IV water quality suitable for crops based on PP. 82/2001.
The results revealed that coal-FA, biomass-FA and mix-FA increased tree height of acacia significantly compared to control and complete control treatments. Without fly ash, the average of acacia tree height is about 95.16 cm, 193.6 cm and 339.4 cm at 30 DAA, 60 DAA and 210 DAA respectively. With biomass-FA 3 kg ha\(^{-1}\) tree height increased to 111.8 cm, 230.1 cm and 365.5 cm at 30 DAA, 60 DAA and 210 DAA, respectively. In general, higher dose of FA, tree height of acacia will be higher.

Acacia tree with FA treatment increased trunk diameter of acacia significantly. Acacia that apply with 3 kg biomass-FA showed the biggest trunk consistently until 210 DAA. Without FA trunk, the Acacia tree measured about 1.01 cm, 2.43 cm and 5.49 cm at 30 DAA, 60 DAA and 210 DAA, respectively. Meanwhile with biomass-FA 3 kg tree\(^{-1}\), trunk diameter increased significantly to 1.3 cm, 3.13 cm and 6.24 cm at 30 DAA, 60 DAA and 210 DAA respectively. These results were not significantly different with coal-FA and mix-FA. From this agronomic aspect, fly ash application to acacia tree on peatland has shown positive impact to the growth of acacia tree. The higher dose of FA applied to acacia trees, tends the better plants growth will be attained, but statistically not significantly different.

**Table 8.** Effect of coal-FA, biomass-FA and mix-FA to acacia tree height and trunk diameter until 210 DAA.

| Treatments   | Tree height (cm) | Trunk diameter (cm) |
|--------------|------------------|---------------------|
|              | 30 DAA \(^{*)}\ | 60 DAA | 210 DAA | 30 DAA | 60 DAA | 210 DAA |
| Biomass-FA 1.5 | 107.0 ab         | 192.4 bc | 351.3 ab | 1.15 ab | 2.74 bc | 5.84 ab |
| Biomass-FA 3.0 | 111.8 a          | 230.1 a | 365.5 a | 1.30 a | 3.13 a | 6.24 a |
| Coal-FA 1.5   | 109.6 a          | 212.6 abc | 337.8 ab | 1.27 a | 2.73 bc | 5.73 b |
| Coal-FA 3.0   | 106.3 abc        | 216.2 ab | 318.1 ab | 1.13 ab | 2.77 b | 5.52 bc |
| Mix-FA 1.5    | 104.3 bc         | 214.2 abc | 350.3 ab | 1.22 a | 2.53 bcd | 5.66 bc |
| Mix-FA 3.0    | 109.1 a          | 223.4 a | 362.2 ab | 1.18 ab | 2.82 b | 5.70 b |
| Complete control | 95.16 c        | 193.6 bc | 339.4 ab | 1.01 bc | 2.43 cd | 5.49 bc |
| Control       | 95.7 c           | 190.3 c | 314.8 b | 0.96 c | 2.37 d | 5.32 c |

Remarks: \(^{*})\ DAA = days after FA application, Number followed by the same letter showed un-significantly differences (P 0.05).

4. Conclusions

Heavy metal concentration in groundwater around acacia trees treated with biomass fly ash, coal fly ash and mix fly ash showed no significantly different with control treatment. Concentration of the heavy metals were still below the water quality standard for plants stated by the government regulation No. 82/2001. It is mean that fly ash application on acacia trees did not pollute ground water of peatland. The growth of acacia plants significantly increased by applying fly ash as ameliorant on peatland. Among 3 kind of fly ash, biomass fly ash at dose 3 kg plant\(^{-1}\) shown better results compare to coal fly ash and mix fly ash. The application of biomass-fly ash, coal fly ash as well as mix of coal 70% and biomass 30% are usefull to increase acacia tree growth and ecologically friendly to peatland environment.

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