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APPLICATION OF FLY ASH GENERATED FROM A MSW TREATED THERMAL POWER PLANT IN VIETNAM

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Abstract

Fly ash is considered a solid waste material that require special disposal treatment to avoid environmental pollution, especially soil pollution. A municipal solid waste (MSW) thermal power plant in Phu Tho Province, Vietnam produced about 15 tonnes of fly ash per day. Au Viet Resource and Environment Joint Stock Company in Vietnam was founded to utilize the subject fly ash and use it as a soil fertilizer. The purpose of this thesis was to analyse the subject fly ash applicability as a soil ameliorant by investigating fly ash behaviour in Phu Tho soil and studying improvement of Spinacia oleracea (spinach) with the amended fly ash.

There were two individual study project in this thesis to study the application of fly ash in soil. The first project was performed and analysed in Phu Tho Province, Vietnam. Soil sample were collected from 4 different location in Phu Tho Province and mixed with MSW fly ash as different ratio of 5 kg/m^2, 10 kg/m^2 and 15 kg/m^2. Soil analysis targets: pH, cation exchange capacity, organic matter content, water content, percentage of nitrogen, phosphorus, potassium, silicon, iron, concentration of soluble reactive phosphorous, exchangeable potassium, sodium ion, magnesium ion, aluminium ion, manganese, arsenic, boron, cadmium, lead, copper, zinc, were measured. Each measurement for analysing targets was performed once (single analysis). The second project was the plantation of spinach on amended-fly ash soil. 12 meter square of in-ground spinach bed was cultivated with 4 different fertilizer formulars: non-amened fly ash, fly ash amendment at ratio 0.5 kg/m^2, 0.75 kg/m^2 and 1.0 kg/m^2 with biological fertilizer as suggested supplement.

Phu Tho soil sample results show significant increase in soil pH, nutritious cations, silicon and heavy metals concentration. Due to single analysis of soil sample and sample assembling condition, the result of soil sample analysis shows quite a confusion and problematic in discussion. However, improvement of soil fertility and acidity buffering were observed from the applied fly ash soil sample analysis. The study also indicated enhancement of nutrition exchange capacity due to the increase of cation in the soil. The study experiment of planting spinach in fly ash amended soil also shows improvements. As compared to non-amended fly ash spinach, average plant yield experienced improvement of 11.51%, 15.50% and 33.95% according to the increase of fly ash proportion.

Keywords

Fly ash, bio fly ash, soil remediation, vegetable yield, Phu Tho soil, circular economy

CONTENTS

1 INTRODUCTION

Municipal solid waste (MSW) management is one of Vietnamese government biggest environmental concerns at the moment. With rapid increase in population, especially in major cities, the amount of trash produced a day can reach up to 1000-2000 tonnes. The traditional solid waste disposal method that has been deployed by the govern departments in Vietnam is landfilling without proper layering and monitoring. This disposing method is environmentally and economically unsuitable causing soil and air pollution, consuming potential land area, and after math environmental remediation cost. United Expert Investments Limited Company (UEI Ltd.) introduced a more reasonable disposal method of mass combustion of waste. Together with Au Viet Resource and Environment Joint Stock Company, UEI Company is to build a municipal solid waste (MSW) thermal power plant in Phu Tho Province, Northern Vietnam. This power plant is to incinerate 500 tonnes of waste per day. Solid waste incineration also produces by-product waste such as waste water, bottom ash, and fly ash.

The purpose of this thesis is to investigate fly ash applicability in agriculture soil as raw material so that the produced solid waste is treated and commercialized at the same time. Promoting circular economy concept to the market, fly ash application reduce the cost for fly ash disposal and gain money from commercializing fly ash as a new fertilizer. However, the fact that fly ash is considered a toxic solid waste due to high content of heavy metals, the application of fly ash need profound learning before being used in soil for cultivating.

There are two separate study experiment done in this thesis to investigate and promote the use of fly ash amendment on cultivating soil. Phu Tho soil is sampled and mixed with fly ash to study fly ash behaviour in cultivating soil engaging damaged/low nutrient soil for better remediating reaction. Analysis of soil sample is done by the help of certified Northern Mountainous Agriculture and Forestry Science Institute located in Phu Tho Province to guarantee the liability of the result. The second study experiment of planting spinach (Spinacia oleracea) is performed in Gia Lam, Hanoi. Study example Spinacia oleracea is a familiar vegetation production in local Vietnam with market substantial consumption.

2 LITERATURE REVIEW AND THEORETICAL BACKGROUND

The study of MSW fly ash applicability is conducted in cultivating soils in Vietnam based on literature reviews and studies of the same subject. As fly ash, especially MSW incinerated fly ash, achieve high level dosage of heavy metal and has potential of leaching, a thorough and define understanding of fly ash is essential. The studies provide general review on the possible application of fly ash in agriculture with field exercises that suggest the fly ash dosage used in Phu Tho soil sample analysis and the planting of spinach in fly ash amended soil in Gia Lam, Hanoi. With high possibility of benefiting soil physical and chemical characteristic when applied, MSW fly ash studies are being exercise on countries with high potential in agriculture such as India, China and Vietnam.

The documentation of fly ash utilizations and works in publishing the book: A Review of fly ash possible applications by Professor Nguyen Xuan Nguyen (chief of Au Viet Company) plays an important role in accounting for information and the rate of fly ash application in Vietnam soil as well as Vietnam domestic waste elements, which was collected and analysed. This thesis study result will act as an example of fly ash application in Vietnam soil that can be referred to in Au Viet publication. This chapter will provide a brief understanding of fly ash characteristic and application in agriculture, with combusted municipal solid waste background.

2.1 Municipal solid waste thermal power plant in Phu Tho Province

Phu Tho Province is located in the Northern part of Vietnam and has the population of more than 1.4 million. Currently according to the statistic evaluation, the average amount of waste generated from urban areas (city) is about 1.2 kg/person/day and rural areas (town) is 0.8 kg/person/day. So, the amount of MSW generating within Phu Tho province can reach up to 700 tonnes per day (UEI-Au Viet, 2017).

Generally, the waste sorting and disposal in Vietnam is not well managed and the most popular method is landfill disposal, which has multiple disadvantages such as land area shortage and environment pollution. Landfills in Vietnam are currently experiencing no monitoring and are not meeting any environmental criteria for safe disposal standards. Therefore, the option of landfill disposal for waste in general is strongly limited by local government and alternatives are being considered. Proposing an improving and sustainable method for Phu Tho waste disposal problem, United Expert Investments Limited Company in partnership with Au Viet Resource and Environment Joint Stock Company has invested a project to build a MSW thermal power plant sourcing 500 tonnes of domestic waste and generating electricity for commerce.

Though UEI Ltd. Company investment in Phu tho would resolve the stagnant out flow of waste in the province, the process of incinerating and waste-to-energy transformation is not a closed-loop process as it also producing by-products such as flue gas and fly ash. As partnership with UEI Ltd. cooperation, Au Viet Joint Stock Company is founded with the purpose of using fly ash as raw material for different utilizations practice. Au Viet Company as an intermediate organization to provide the fly ash, disposed from the power plant, for cement replacement application in building material production, agriculture fertilizer and soil ameliorant. About 15 tonnes of fly ash are disposed from the power plant per day mean 5000 tonnes for year, if without the propose application from Au Viet Company local authority would be stressed on waste disposal. Due to its high heavy metal and toxic element concentration, fly ash is considered toxic waste and will require further treatment before disposal to reduce environmental impact on soils and the atmosphere which remarkably costing the power plant investor and Phu Tho Province governance (UEI-Au Viet, 2017).

2.2 Municipal solid waste in Vietnam

According to Vietnam 2011 National Environmental Report: Municipal Solid Waste, 54-77.1% of the total waste collected are potentially recycled and use as organic fertilizer, plastic takes up to 8-16% of the total waste and 2% are heavy metals. Occasionally, hazardous waste is also gathered into municipal waste by mistake; but this only account for 1% out of the total. Represented table 1 is an example of the waste percentage collected from the capital of Vietnam, Hanoi. The majority of waste matter is organic waste (53.81%), followed by plastic content and paper (13.57% and 6.53%); low percentage of hazardous waste (0.17%) is also observed.

Municipal waste content partly determine suitable technology uses for incineration, and the fly ash element at the end of the combustion process. Waste with higher moisture content requires longer drying time and lower burning rate (Liang et al., 2008, 7238). Wastes that appear to have high water content are organic wastes such as food waste.

Table 1. Percentage of Hanoi municipal waste content

No.	Municipal waste content	Percent (%)
1	Organic matter	53.81
2	Paper	6.53
3	Fabric	5.82
4	Wood	2.51
5	Plastic	13.57
6	Leather and rubber	0.15
7	Metal	0.87
8	Glass	1.87
9	Ceramic	0.39
10	Soil and sand	6.29
11	Coal ash	3.1
12	Hazardous	0.17
13	Sludge	4.34
14	Other	0.58
	Total	**100%**

The National Environmental Report on Municipal Solid Waste only featuring a few large cities in Vietnam which does not include the study Province, Phu Tho.

Therefore, samples of waste were gathered from several collecting points in Phu Tho Province by Au Viet Company to analyse water content for application purposes (table 2). As a result, 60-65 % of total waste are organic and food waste which has high water content; soaked and drained waste has high water content of 40-41%; overnight room temperature (25-28°C) waste dried at 105°C has water content of 20-25% (UEI-Au Viet, 2017).

Table 2. Phu Tho waste's water content

No.	Waste	Water content	
		Weight (kg)	***Percentage (%)***
1	Paper, wool	0.18	8.5
2	Nylon, synthetic, rubber, leather	0.20	9.4
3	Wood, straw, thatch	0.70	32.9
4	Food waste	0.73	34.3
5	Incombustible	0.32	15.0
6	**Total**	**2.13**	**100**
7	Wet weight	2.70	
8	Dry weight	1.60	
9	Water content	1.10	40.7

2.3 Fly ash and MSW fly ash

Fly ash (FA) is a coal combustion product generated from the coal-fired boilers along with flue gases. It is a powdery matter that is mechanically or electrically collected from the boilers. Fly ash can be classified into two main type as class F and class C depending on their chemical composition (amount of calcium, silica, alumina, and iron content). Fly ash that is categorized as class F usually has higher silica, alumina and iron content (more than 70%) and low lime content (less than 10%) while class C fly ash has higher content of lime (more than 20%). Class C fly ash is generally produced from young lignite/sub bituminous coal that results in consisting pozzolanic and self-cementing properties; unlike class F fly ash, which is the by-product from the combustion of anthracite and bituminous coal, that to be managed need Portland cement, quicklime, or hydrated lime react in water to produce cement-like mixture (Dwivedi et al., 2014, 30-35). Fly ash utilization option depends greatly on the physical and chemical content of fly ash which is determined by the content of input raw material, furnace design, furnace operation and method of particulate control.

MSW fly ash is the by-product resulted from the combustion of raw domestic waste, which in this case study scenario is the solid waste collected across Phu Tho Province. Fly ash physical's and chemical's composition depends greatly on input raw municipal solid waste due to the various life style and recycling method of waste in different countries. There are generally two type of combusting domestic waste: first is to sort out glass and ferrous metal before actual incineration process; second is combusting the collected municipal waste as it is called mass-burn. Pre-sorting combustion product usually has higher calories value (Ferreira et al. 2003, 201-216). Other factors can affect the MSW fly ash are the operational conditions, the type of incinerator and the design of air pollution control system. The composition of the fly ash decides its applicable method as well as suitable level of exercises. Because of the waste variation content with such as composite waste, inert waste and electronic waste, the ash produced from the furnace display a large number of toxic material. And due to its fine physical properties, fly ash leaching ability makes it not environmentally suitable even for landfilling, as soil pollution poses a threat the environment.

Major chemical composition in fly ash are Si, Al, Fe, Mg, Ca, K, Na and Cl; and common oxides are SiO_2, Al_2O_3, CaO, Fe_2O_3, Na_2O, K_2O. For heavy metals, Cr, Cu, Hg, Ni, Cd, Zn and Pb are the most commonly found in MSW ash. MSW usually incinerate at temperature at least 850°C. Detail of waste incineration to create electricity process is demonstrated in figure 1. The incineration of municipal waste provided heat to the boiler creating steam which drives the turbine to generate electricity. During the process of combusting the waste, fly ash is collected using exhausted gas cleaning system (bag filter) (Lam, 2010, 1943-1968).

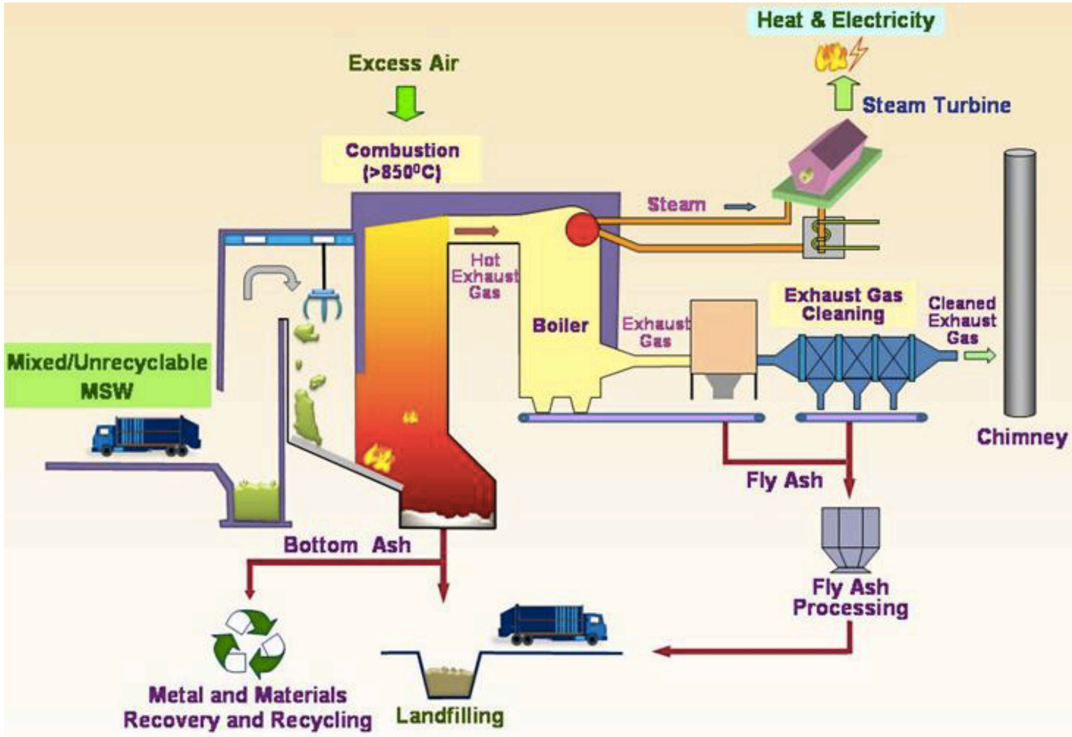


Figure 1. Schematic Diagram of the MSW incineration process (Source: Lam, 2010, p.1944)

Classification of MSW can be different from coal fly ash, it can be classified according to its physical properties or its chemical properties. Physical properties include: particle size distribution, moisture content, bulk density, compressive strength, permeability and porosity. Chemical properties include: chemical composition, loss on ignition, heavy metals and leachability, organic constituents, chloride content. The content in MSW fly ash varies on the recycling and sorting system in different countries and regions. As in Finland, domestic waste is well managed and separated by the people so a considerable amount of waste is recycled. In contrast, the majority of Vietnam municipal waste is disposed in the land fill or incinerated without any sorting method or recycling, only a small part of the waste is recycled in individual recycling point. The raw material (the waste) content effects the possibility of utilizing fly ash in variance application.

Fly ash is typically disposed in two different method, dry method and wet method (Anushree and Alka, 2009, 333-366). Normally, not handled fly ash is dump straight to landfill or fly ash basin as dry method or wash away by water into ash pond (Jala, 2006, 1136-1147). Both of this disposal method cause pollution to local environment, especially soil.

MSW fly ash account for numerous application such as construction, geotechnical materials, glasses and ceramics, agriculture, stabilizing agent, adsorbents and zeolite production. Fly ash has been put into use by multiple countries in the world, including Vietnam. Nonetheless, construction application usually take the lots of total usage. For instant, a research by Manoj Kumar Tiwari1, Dr. Samir Bajpai and Dr Umesh. Kumar. Dewangan suggested that 42.26% of total fly ash is used in cement production in India during the year 2014-2015 (Figure 2). Whereas the rate of fly ash usage in agriculture only account for 1.93%. Though the production of fly ash in India increases significantly during the period 1998-2015, the utilization amount of utilization in agriculture remain low. The total use of fly ash raised from about 10 million tonnes in 1998-99 to over 100 tonnes in 2014-15 in India, while the potion for agriculture application only share a small part of 1.97 million tonnes (period 2014-15). As fly ash matter include a wide range of chemical and high leaching probability if not treated the right way, it is rarely being adopted in agriculture.

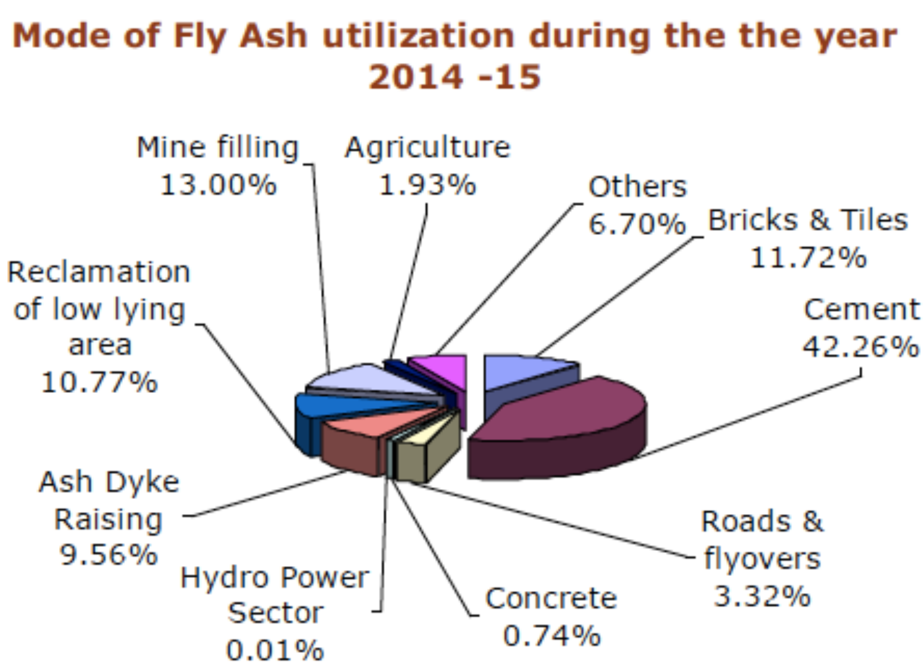


Figure 2. The pie diagram showing the modes of utilization of fly ash during the Year 2014-15 in India. (CEA, 2015, p.21)

2.4 Fly ash in soil remediation

Fly ash can be acidic or alkaline depends on the source of combustion material. Fly ash pH can range from 4.5 to 12.0 based on the sulphur content of the combustion material so fly ash can be used as a buffer agent to adjust soil pH, neutralize acidic soil. The acidic component in the soil react with the lime in fly ash generates elements such as S, B, Mo in the form that favour the soil environment (Sahu et al. 2017, 873-880). Studies in India show that the use of fly ash as liming material are not only using hydroxide and carbonate salts to neutralize soil pH but also provide nutrients to the plant (West, 2015). Necessary ion accumulation of metals such as Zn, Mn, Cu in plant might occured due to the addition of high metal content fly ash that increase soil conductivity (Sahu et al. 2017, 873-880).

Fly ash is also proven to improve soil physical texture and increase porosity. According to a long-term study of agriculture soil in Quebec, cultivating soil after season of farming and harvesting loosen the structural stability and productivity, water holding capacity, and experience in reduction of organic matter even when fertilizer amendment is taken to improve nutrient availability (Martel et al. 1980, 411-420). Studies have proven that the application of fly ash can modify soil texture changing sandy and clayey soil into potential cultivating loamy soil. Application of fly ash at 70 tonnes per hectare dosage in land reclamation project in Eastern United States demonstrated the chemical and physical advantages of applying fly ash in wasted land and agriculture soil (Capp,1978, 339-353). Soil bulk density can by significantly reduced when being applied with fly ash. And as a result, soil porosity along with root penetration capacity can increase, which also help in reduction of surface encrustation. Increase in the use of fly ash in normal field soil is verified to increase in soil water retention capacity and porosity (Korcak RF, 1995).

Unlike the advantages of fly ash on soil physical and chemical characteristic, there are several adverse effects of fly ash on biological characteristic of soil. Due to high levels of heavy metals element and soluble salts existence in unweathered fly ash, when being applied on sandy soil, fly ash appeared to inhibit microbial respiration, enzymatic activity and soil nitrogen cycling processes. The effects were proven by several laboratory experiments reviews by Gayari Sahu and her colleagues (Sahu et al. 2017, 873-880). Fly ash, can be exposed to the soil environment, consist of toxic element such as boron, the main limiting factor in reduction of microbial activities. By combining alkaline fly ash and animal manual, fly ash will not anymore be toxic to the soil with more Ca and Mg added into the soil balancing the monovalent and divalent cations ratio. With the addition of cation ion into the soil from fly ash (especially in clay soil), Ca replace Na in soil and therefore improve soil stability and porosity. Creating a more substantial living environment for crop and plant to survive, fly ash amendment in soil is deeply studied with application practice for agriculture crops such as rice and wheat; and the result is beneficial.

2.5 Fly ash in improving plant yield and quality

Fly ash contain almost all required nutrient for plant growth and therefore is much suitable for cultivation application. Essential element for plant found in fly ash exist in form of ion in cooperate with physical, chemical and biological effect of fly ash as mentioned the previous section, shows benefits when applied as fertilizer for crop production. Jala and colleges has reviewed the benefit of fly ash addition in crop yield improvement suggesting that the application generally increase crop yield and improve plant nutrient uptake.

According to Jala (et al.2006, 1136-1147) paper, Martens, (1971, 15-19), Page (et al. 1979, 83-120), Hill and Lamp (1980, 377-384), Elseewi et al. (1980a, 424-428, b, 247-259) and Weinstein (et al. 1989, 291-300) indicated that added fly ash in agriculture soil would improve yield of alfalfa (Medicago sativa), barley (Hordeum vulgare), Bermuda grass (Cynodon dactylon) and white clover (Trifolium repens). Further studies on crop yield experienced with fly ash application shows significant increase. At application rate of 50 tonnes of fly ash per hectare measured an increase of 5-20% for cereal crops and vegetable crops, 20-30% for plantation crops, 5-10% for wheat (40% in alkaline soil and 65% in paddy soil), 13-17% for rice, 36-40% for maize, 25-37 % for potato, 28-32% for mustard and 55-58% for red gram (Arivazhagan et al.2011)

2.6 Fly ash management and utilization available legislation

Fly ash is considered a toxic solid waste due to its potential harmful components such as arsenic, mercury, cadmium. Electricity power plant usually dispose their solid waste offsite or in landfills and surface impoundment (RTI, n.d). In the case of fly ash disposal management in Vietnam, residues from thermal power plan are hardly collected and treated to prevent environmental pollutions (Baodatviet, 2011). There's not yet verifies publications on the use of ash, slag standards, technical regulations, technical guidelines and regulations, as it was proposed in Decision No. 452/QD-TTg dated April 12, 2017, approving the proposal to boost treatment and use of ash, slag and gypsum discharged from thermal power plants, chemical and fertilizer plants for production of building materials and for use in construction projects.

According to Section 30 in Decree No. 38/2015/NĐ-CP by Vietnamese Government about waste management, if generated fly ash from thermal power plant is not reused, recycled or self-managed will be transferred and disposed by industrial solid waste treatment unit. The fly ash disposed as solid waste accordingly to Decree No. 38/2015/NĐ-CP will be disposed at the landfill which entitled toxic component to leach into soil. Adding up, regulations and circulating instruction in fly ash utilization rate is unobtainable. The feasibility of justifying regulation addressing fly ash application rate in Vietnam agriculture soil is limited. Thou there are guideline intructions and approvals of fly ash utilization in construction materials such as Decision No. 452/QD-TTg dated April 12, 2017, approving the proposal to boost treatment and use of ash, slag and gypsum discharged from thermal power plants, chemical and fertilizer plants for production of building materials and for use in construction project.

However, problem of not finding specific fly ash agriculture utilization instruction happens not only in Vietnam but other countries as well. Specific guidelines to the agricultural utilization of fly ash are established by only just a few jurisdictions. An example in Australia, regulation can only be found in those of New South Wales, where clear guidelines for producers, suppliers and users of ash in agriculture are presented. Maximum elemental concentrations not to exceed 100 mg/kg for Pb, 10 mg/kg for Cd, and 5 mg/kg for Hg. No soil type is addressed under this regulatory requirement. Other requirements taken into account include: hot-water-soluble Boron (B) concentration (using a CaCl2 extraction method) not to exceed 60 mg/kg; electrical conductivity (EC) not to exceed 4.0 dS/m; full chemical characterization of ash must be conducted and redone every 3 years or when the sources change; user needs to ensure that fly ash is incorporated in soil with constant measurement on element concentration (Yunusa et al. 2012, 559-600).

Detailed study of radio nuclides and heavy metals content in fly ashes and their impact on agriculture use has been undertaken in association with Dept. of Atomic Energy, Govt. of India and Indian Council of Medical Research, Govt. of India. Chemical as well as biological studies are conducted concluding that the levels of radio nuclides and heavy metals content in fly ashes, fly ash admixed soil and crop produce safe/normal range are: 17.1-28.0 ppm for boron, 2.5-6.7 for Mo, 1.0-4.0 for Arsenic and 1.6-2.6 for Selenium (Kumar and Jha, 2014). These studies can act as a guideline/example to develop researches and suggestion for legislation and regulation in Vietnam regarding the subject.

3 MATERIAL AND METHOD(S)

3.1 Subject fly ash analysis

The subject fly ash for this thesis is a by-product from the incineration process of municipal solid waste in Phu Tho Province and experienced fermenting process to sufficiently suitable for land application. The fly ash was sent to analysed in Northern Mountainous Agriculture and Forestry Science Institute for research studies and marketing purposes by Au Viet Company. The analysis results are recorded and published by Au Viet company along with other fly ash fertilizer related documents.

Fly ash physiochemical analysis results consist of: fly ash pH level (10.68), water content (1.63%), nitrogen (0.196%), phosphorous (0.107%), potassium (19.39%), sodium (0.11%), magnesium (0.256%), iron (0.94%), copper (9.7 ppm), zinc (75.55

ppm), manganese (59.3 ppm), lead (14.37 ppm), arsenic (7.53 ppm), aluminium (27.16 ppm), silicon (0.18%), boron (12.03 ppm), and cation exchange capacity (2.81 μS/cm). Additional detail information of executed institute and the result of fly ash analysis is attached in APPENDIX III.

3.2 Application of fly ash as soil ameliorant in Phu Tho Province

Soil samples are collected in different location as according:
(1) Paper material Research Institute located in Phu Ninh Commune, Phu Ninh District, Phu Tho Province.
(2) Dong A Centre for Research, Conservation and Development of Medicinal Plant Northern region located in Te Le Commune, Tam Nong District, Phu Tho Province.
(3) Northern Mountainous Agriculture and Forestry Science Institute located in Phu Ho Commune, Phu Tho Province.
(4) Tran Van Kinh private grapefruit garden located in Bang Luan Commune, Doan Hung District, Phu Tho Province.

The samples were collected from 4 different sites across Phu Tho Province with each site represent a plant that has local economic potential and is widely introduced into the market. The soil sample location is provided by local professional team conducted regards to Northern Mountainous Agriculture and Forestry Science Institute to acquire most representative for each plant and suggest the exact sample collecting point as well as making sure the process of getting the sample is by standard. Some soil location is taken from site plant that have low nutrient condition intentionally to investigate the probability of using fly ash as soil ameliorant. Most popular cultivating soil in the area is loamy soil which is most desirable for plant growth soil (Sommers, 1984). Details of soil sample collections and sample mark is listed in APPENDIX I; the marks are specified depends on the sample location such as PN1 stands for sample number 1 at Phu Ninh Commune, Phu Ninh District.

Total of 16 soil samples are collected in different locations and mixed with bio fly ash to study its potential as soil ameliorant. The samples acquired are 30 – 50 cm from the surface bed using a specific soil collector called Edelman Clay Augers

(Figure 3). The augers are assembled with 3 parts including handle and blade. To collect the soil sample, the augers are used to dig vertically to the ground. The first 20 cm layer of organic matter is removed to avoid external impact factor on the sample. The soil collected from the earth is put directly into a plastic zip bag to secure moisturise content and prevent other factors to affect the sample. The sample hole created by the augers has a diameter of around 11-12 cm and depth of 30 – 50 cm (Figure 4)

Figure 3. Edelman Clay Augers tool for collecting soil (Tran, 2018a)

1, 2, 3 – Parts of the augers

4 – Spanner (use for disassembling the augers)

5 – Angled spatula (to remove soil from the augers)

6 – Assembled Edelman Clay Augers

Figure 4. Sample site (hole after soil was collected) (Tran, 2018b)

The collected samples (from 4 different sites) were transported to Northern Mountainous Agriculture and Forestry Science Institute for weigh and analysis. Bio fly ash ratio is calculated and prepared according to APPENDIX II. Based on soil sample type bulk density, loamy and sandy loam soil are being studied, the amount of acquired soil are calculated. The sample load/weight for analysis is limited as the experiment is presented as 5 - 15kg of fly ash application for each square meter soil and the depth of soil sample is 30-50 cm from the surface which can be explained as 800kg of soil per square meter of analysis. Therefore, reasonal equivalent amount of soil and fly ash sample (500g of sample) is calculated and formulated before submitting it to the analysis institution.

The process of soil sample and fly ash content calculation is prepared prior to the sample assembling date; and analysis samples were scaled at the institution with institution professionals support. Each sample weighs approximately 500 grams (soil + bio fly ash) with slight different of two decimals. The samples after being mixed with the right ratio of fly ash will then being naturally set/dry for 10 days before proceeding into analysis. The analysis experiments are performed by professionals from the Science Institute in Phu Tho Province according to detail requirements from Au Viet Resource and Environment Joint Stock Company. The sample are marked according to the site collection location as mentioned above. Each site is recorded with 4 sample; sample number 1 is set as control sample for comparison which as non-fly ash application. Sample 2, 3 and 4 present the level of fly ash application of 5 kg/m^2, 10 kg/m^2 and 15 kg/m^2 respectively. For example, sample PH3 presents soil sample from Phu Ho Commune present analysis result for fly ash application of 10kg/m^2 which equal to 100 tonnes of fly ash per hectare if applied on a bigger scale.

3.3 Application of fly ash in improving Spinacia oleracea yield and quality in Gia Lam, Hanoi

Research on crop yield and quality improvement by fly ash application has been developing in countries such as Australia. For instant, a study with field application shows significant yield improvement of wheat and canola in Richmond and Merredin, Western Australia (Yunusa et al. 2012). However, there's not enough study and field test on short-term vegetable. A small experiment on Spinacia oleracea plant growth will be conducted with the support of Hanoi University of Agriculture.

Figure 5. Application of bio fly ash on spinach (formula 2 – 0.5kgFA/m^2) (Tran, 2018)

The content and targets of the planting process and fertilizing Spinacia oleracea using bio fly ash are applied according to table 3. Total cultivating area is 12 m^2 divided into a 12-plot area; each plot represents 1 formula (Figure 5 present 0.5kg of fly ash application on plot GL2018 - 2.3). To formulate defined standard analysis data, each plot sample formula is repeated 3 times. With 4 suggested formulas, the field experiment triple repetition and 5 collected results for each formula we have 4 formulas x 3 times repetition x 5 plants = 60 plant results for 12 m^2. Due to fly ash dusting physical characteristic size from 0.5 μm to 100 μm is easy to penetrate the soil and get absorbed by plant, fly ash potion was cutback from the initial planned application from 0.5kg/m^2, 1kg/m^2, 1.5kg/m^2 to 0.5kg/m^2, 0.75kg/m^2, 1kg/m^2 accordingly.

Table 3. Bio fly ash application on Spinacia oleracea plant

No.	**Sample mark**	**Cultivating area** *(m^2)*	**Bio fly ash amendment** *(kg/m^2)*	**Repeat** *(times)*	**Note**
1	GL2018 - 1	3	0	3	Control
2	GL2018 - 2	3	0.5	3	
3	GL2018 - 3	3	0.75	3	
4	GL2018 - 4	3	1.0	3	

Listed sample marks represent the formula of applied fly ash as well as the formula number and series repetition. Sample mark GL2018 shows the location and experiment date. The first fertilizer formula consists of 0.4 kg of microbiological fertilizer, 0.015 kg urea, 0.015 phosphate fertilizer and 0.010 potassium chloride is chosen as control samples. Cultivating area for formula 2, 3 and 4 are fertilized same as series sample mark 1, plus 0.5kg, 0.75kg and 1kg fly ash amendment, respectively. During the process of planting the spinach, height, leaves number and pest intrusion are detailed observed. Plant growth monitoring is conducted every 5 days to tract the growth of spinach and identify any sudden changes in plant. The result is recorded in Field Experiment Diary (APPENDIX VII).

Measured content in Field Experiment Diary is based on attributes in table 4 reflecting the spinach growth and possible notable quality improvement. The measure requirements are plant height (cm), root length (cm), number of leaves, leaves colour and pest intrusion for plant growth; plant yield (m^2) ans sensible evaluation for plant quality. Occasional plant measurement includes measure of plant height, number of leaves and observe the possibility of pest intrusion. The evaluation is carried out by the author and the company assistant/supervisor in adequate of the result. After the cultivating period, the spinach was harvested and weighted by plot to compare yield improvement ability of fly ash application. In addition, root length was also measure to suggest the outcome of plant quality.

Table 4. Attributes of measuring plant growth and yield for Spinach cultivating experiment in Gia Lam, Hanoi

No.	Subject	Growth/yield	Parameter	Note
1	Plant growth	Plant height	Cm	
2		Root length	Cm	
4		Number of leaves	number	
5		Leaves colour	Good/Neutral/Bad	Details
6		Pest intrusion	High/Neutral/Low	
7	Yield, quality	Plant yield	Kg/m^2	
8		Sensible evaluation	Smell, taste, softness, ect	Details

4 RESULT AND ANALYSIS

4.1 Application of fly ash as soil ameliorant in Phu Tho Province

Total of 16 soil samples collected from Phu tho Province is submitted to Northern Mountainous Agriculture and Forestry Science Institute for analysis. 21 analytical criteria are set to investigate fly ash behaviour in soil and how it affects soil characteristic. The criteria are soil pH, cation exchange capacity, percentage of organic matter, nitrogen, phosphate, K_2O concentration of several metals (Ca^{2+}, Mg^{2+}, Al^{+}, Mn, Zn, cu, B, Pb, Cd, As, Si), and soil water content. There are 4 soil samples collected from each site with sample 1 as control sample for comparison (for example BL1 is control sample for Bang Luan series of soil samples), sample 2 with 5 kg of added fly ash per meter square, and as accordingly sample 3 and 4 represent 10 kg FA/m^2 and 15 kg FA/m^2. Due to the complicity of recorded results, majority of the criteria results are displayed in individual charts except for some criteria that are grouped for better observed trends.

Figure 6 result demonstrates the effect of fly ash on soil chemical characteristic. With high pH level of 10.68, fly ash application in soil has successfully buffer acidic soil in Bang Luan Commune raising soil pH from 3.65 to 6.15 with application rate of 15 kg fly ash/m^2. Result sample in Phu Ho, Phu Ninh and Te Le trend are not presenting as clear as Bang Luan results, showing that with the application of fly ash, there's an increase in soil pH but not quite significant. Phu Ninh results display confusion at sample PN3 is higher than the other samples at location.

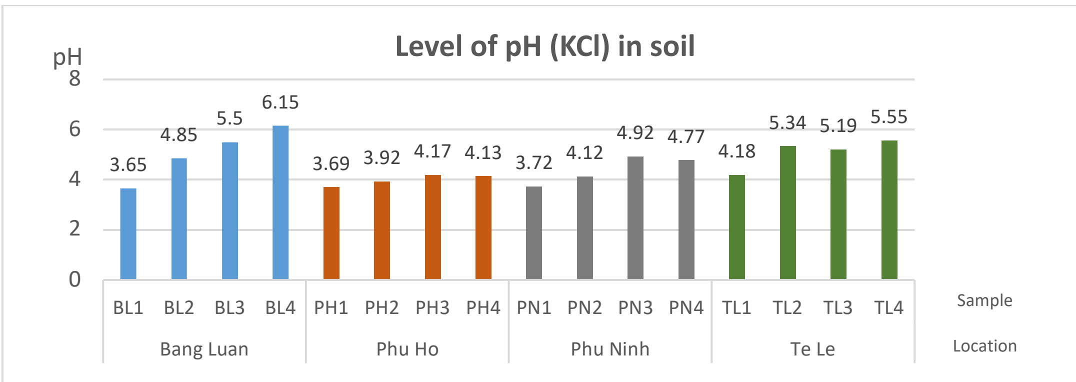


Figure 6. Soil sample pH level with and without fly ash treatment

Results in soil cation exchange capacity (CEC) show no trend whatsoever raising question about the experimenting operation. Bang Luan results revealing a downward trend in CEC composition when fly ash application increase. Results from other location shows a slight increase in soil CEC when compared with control sample 1. However, there are still sample PH2, PH3 and TL3 with Bang Luan result sample demonstrating reduction that require further study.

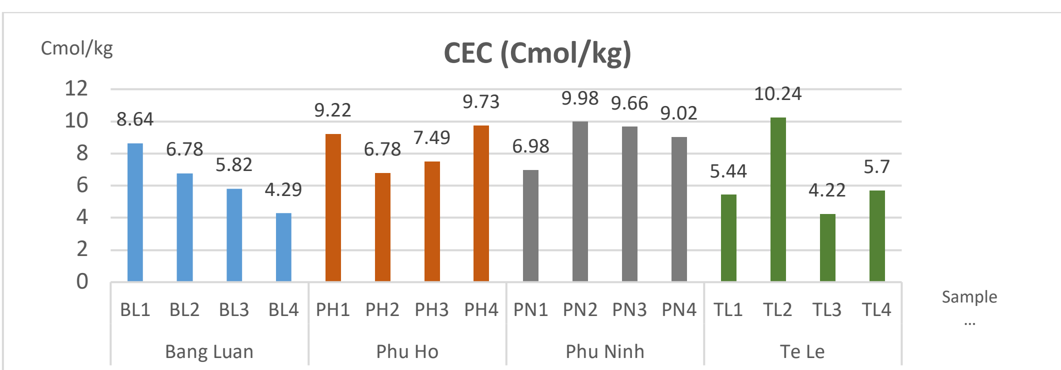


Figure 7. Cation exchange capacity in soil sample

An overall upward trend can be observed from this column chart. With the application of fly ash organic matter (OM) in soil experience an increase for about 0.25-0.4% in Bang Luan, about 0.2-0.6% in Te Le, and most significant evidence is in Phu Ninh with the highest figure of PN3 3.96% OM comparing to 2.22% OM in the control sample PN1.

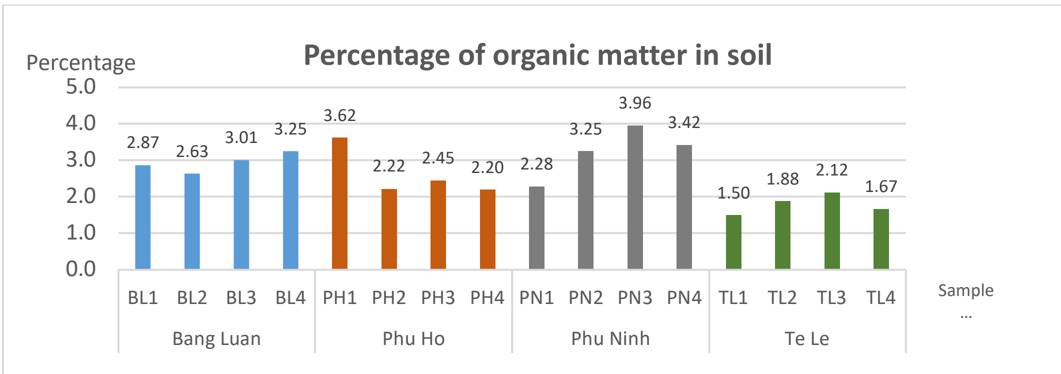
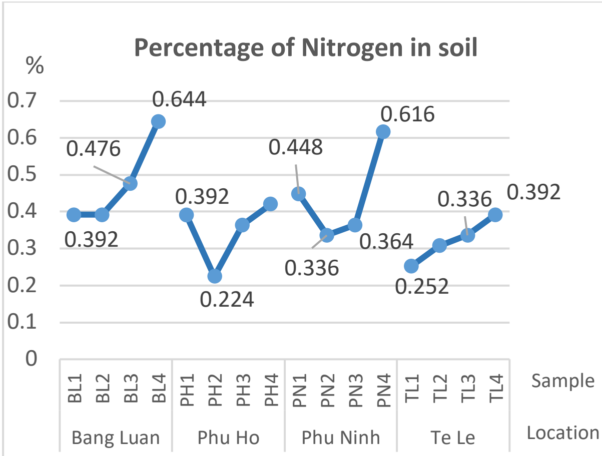


Figure 8. Percentage of organic matter in soil sample

Bang Luan soil sample result shows the most dramatic increase in nitrogen (N) percentage from 0.392% to 0.644%. Another increasing trend that can be studied from nitrogen percentage line chart is Te Le results of clear gradual risen from 0.252% to 0.392% N. Nitrogen percentage in soil samples in Phu Ho and Phu Ninh experiencing a decrease when the level of applied fly ash are 5 kg/m^2 and 10 kg/m^2, then increase with fly ash dosage of 15 kg/m^2 as compared to control samples. Percentage of phosphorous and potassium in soil sample result fluctuate with or without fly ash application. Exceptional potassium figure of Te Le samples appeared in a different data area with the rest of the obtained results.



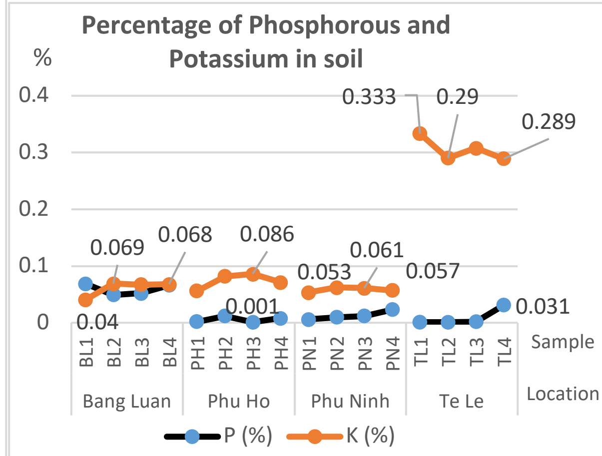


Figure 9. Line chart with marker presenting percentage of nitrogen, total phosphorous and total potassium in soil sample

Figure 10 illustrates the amount of measured soluble reactive phosphorus and exchangeable potassium in soil samples. An overall increase of nutrients is observed in this chart with only one abnormal significant statistic of BL2 exchangeable potassium peaking at 57.44 mg/100g soil. An unusual light decrease of soluble reactive phosphorus is recognised in Te Le series of sample. Though Te Le amended fly ash soil sample soluble reactive phosphorus amounts are higher than the control sample, with higher proportion of fly ash added the amount of account phosphorus will decreases.

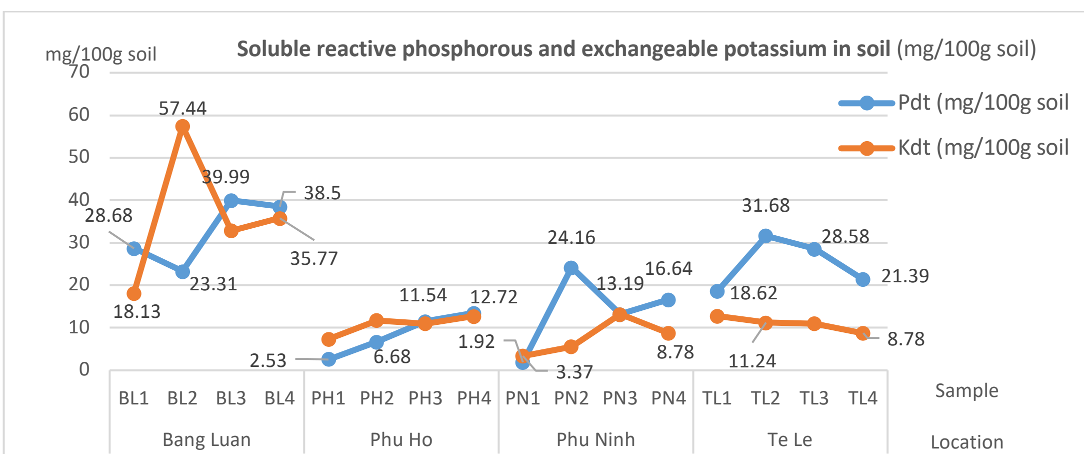


Figure 10. Soluble reactive phosphorous and exchangeable potassium in soil sample (mg/100g soil)

Sample collecting location hold highest water content is Te Le Commune, the medicinal plant unit. However, the column chart shows no course of similarities between sample collected locations. The changes in water content of soil can hardly be measured and analyse with short amount of fly ash resident time in soil making the data in figure 11 only exhibit different location soil water content.

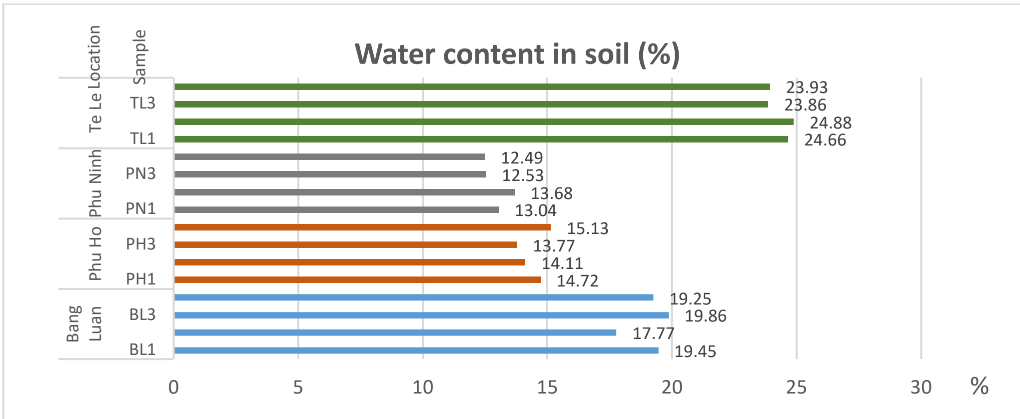
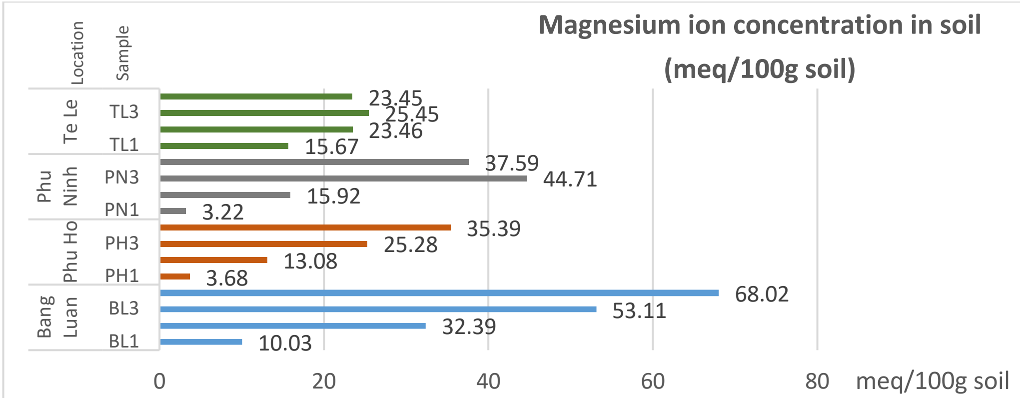


Figure 11. Water content in soil sample

Figure 12 illustrate magnesium and sodium ion concentration in soil sample in two different column chart. With the application of fly ash, significant increase of ion in soil can be observed. As compared with control sample from each location, the result of ion concentration in Bang Luan Commune is most indicative as the amount of magnesium ion increase for (compared with control sample) almost 7 time higher of the BL4 sample with 68.02 meq/100g soil, and 4 times higher of BL4 sodium ion concentration with 8.03 meq/100g soil. Other noticeable escalation is Phu Ninh and Phu Ho soil samples magnesium and sodium ion. Te Le result samples experienced development but not significant.



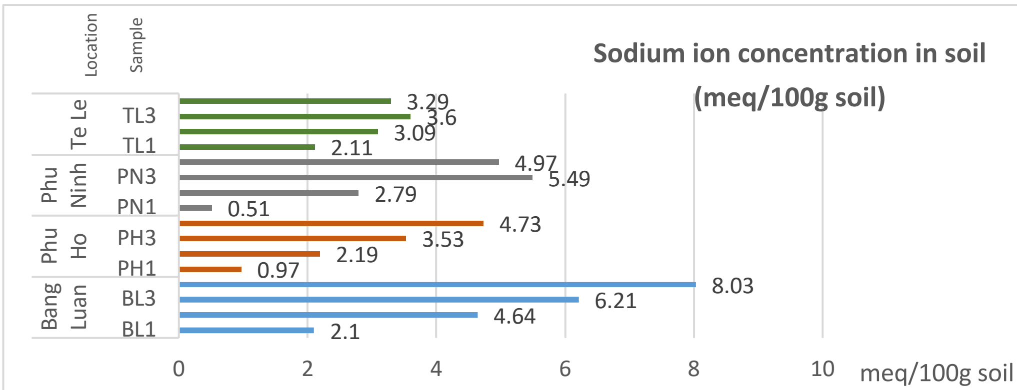
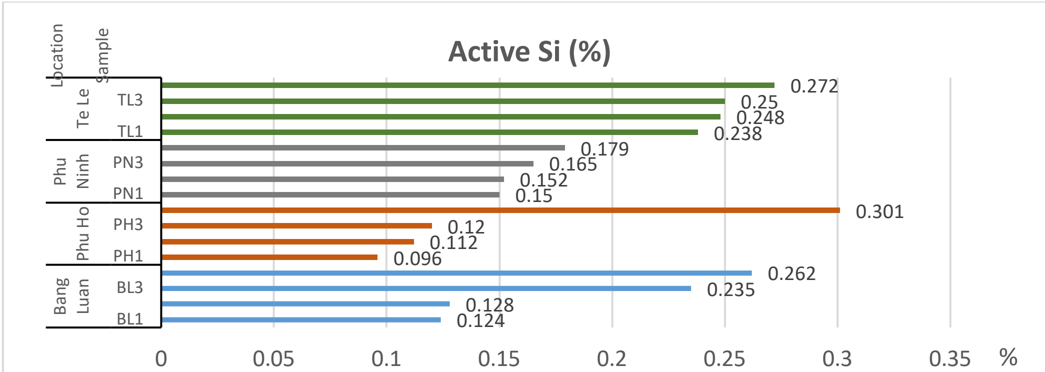


Figure 12. Magnesium and Sodium ion concentration in soil sample (meq/100g soil)

Figure 13 investigate silicon (Si) content in soil sample describing the overall raising of Si in soil. Fly ash acquire for a high amount of Si; therefore, total and active Si merger was expected. In general, a gradual increase of Si is observed in figure 13 except for an unusual peak in active Si content in soil sample PH4. If following the trend of development, PH4 active Si result is expected to fall in range of 0.12% to 0.15%. However, in this case scenario, result shows that active Si content in soil sample PH4 peaked at 0.301% over pass Te Le soil results (that have an overall uplift percentage).



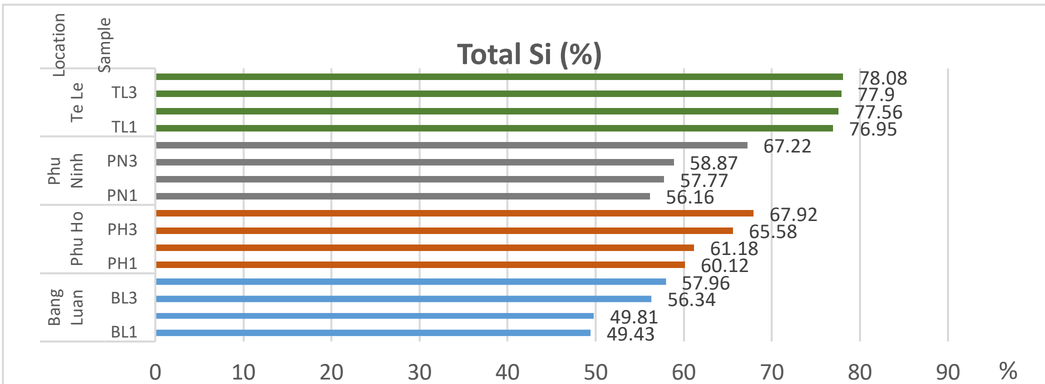


Figure 13. Percentage of total and active silicon in soil sample

According to column chart of iron percentage in soil sample, with the added fly ash, iron percentage in soil decreased for all fly ash amended samples. Lowest observed iron percentage within Bang Luan series sample is BL2 with the decease os almost 1.0%, furthest decrease observable in the chart. Slight decrease is shown in Phu Ninh and Te Le sample series where the amount of iron fell fluctuately.

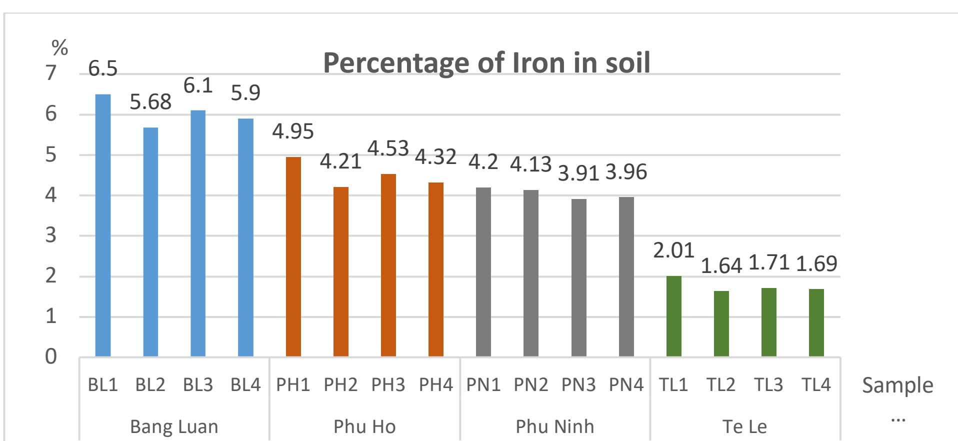


Figure 14. Iron percentage in soil sample

Appeared to experience same downfall as iron content, aluminium (Al^{3+}) content in soil sample also decrease when fly ash is applied. Unlike slight decrease of iron showed in figure 14, figure 15 illustrate a significant drop in Al^{3+} especially in PH4 and PN4 sample (0.3cmol/kg). Control sample PN1 display peak in Al^{3+} content with 1.9 cmol/kg Al^{3+}, followed up by PH1 with 1.8 cmol/kg Al^{3+}.

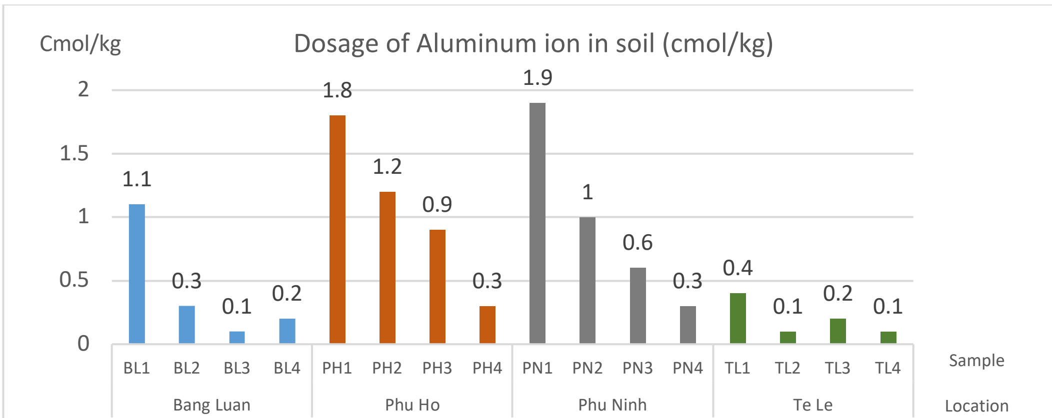


Figure 15. Aluminium ion content in soil sample (cmol/kg)

Figure 16 demonstrate the concentration of manganese (Mn), copper (Cu) and zinc (Zn) in collected soil sample. The only gradual increase that can be observed from the chart is Bang Luan Mn concentration; the higher fly ash dosage application, the increase concentration of Mn in soil sample. However, unlike the upward trend for Bang Luan Mn result, Phu Ho, Phu Ninh and Te Le Mn data show fluctuated and declined results. Most significant changes observed in figure 16 is the drop of Mn concentration of TL 2 sample. Cu and Zn results in soil sample show no representative trend of movement is problematic in analysis of data.

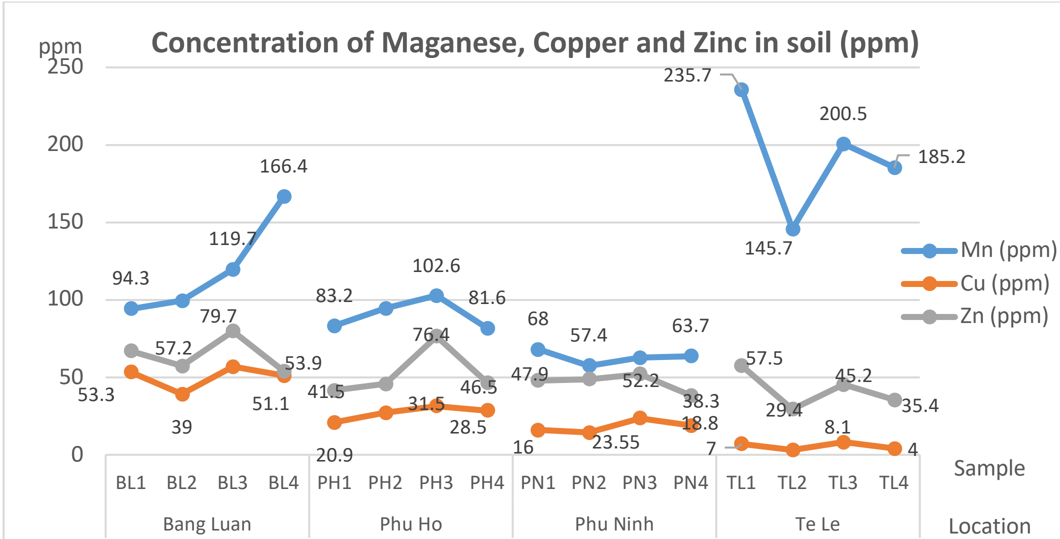


Figure 16. Concentration of Manganese, Copper and Zinc in soil sample (ppm)

The amount of cadmium (Cd) in soil is respectively low and shows no sudden changes in concentration accept for only sample BL4 with the highest point of Cd concentration (0.093ppm) within the total samples. Other results data suggest a fluctuation in soil sample cadmium with the lower Cd concentration found in soil sample PN2 with only 0.021 ppm Cd in soil sample.

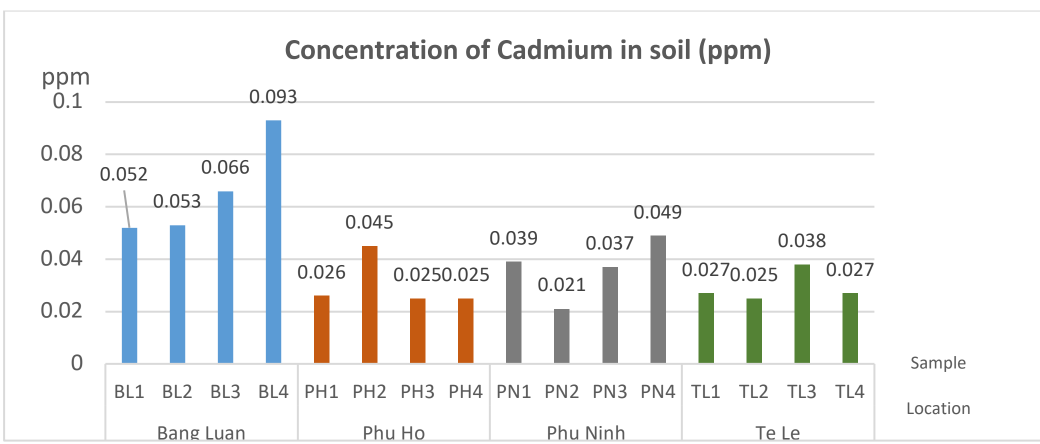


Figure 17. Concentration of Cadmium in soi sample (ppm)

Figure 18 results shows the concentration of boron (B), arsen (As) asn lead (Pb) in soil sample. An overall increase in B and As was observed when boron concentration of PN2 sample is not considered. Result for PN2 boron concentration is 22.95 ppm which exceptionally outburst in soil metal content. This result may happen from false soil sample collecting method or during the analysis procedure.

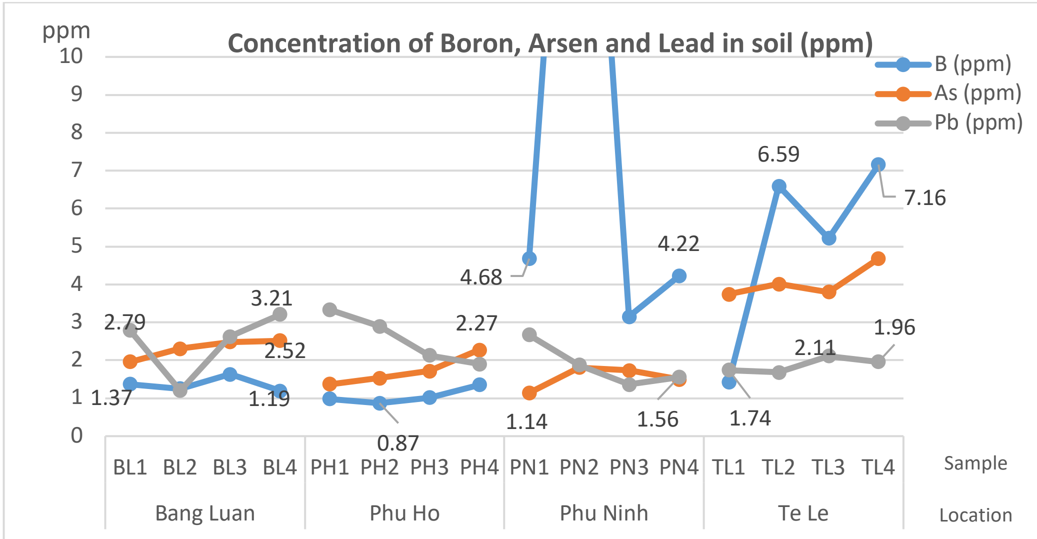


Figure 18. Concentration of Boron, Arsen and Lead in soil sample (ppm)

4.2 Application of fly ash in improving Spinacia oleracea yield and quality in Gia Lam, Hanoi

Spinach growth and yield quality were continuously inspected during the experiment. Spinach height, number of leaves dramatically changes in short period of time; spinach height acceleration can reach up to 7-8 cm in a period of 5 days (GL2018 – 4, 20/04-25/04).

Figure 19 shows spinach growth in 30 days by height measured in Gia lam, Hanoi. The figures appear that float along the line chart display spinach height for formula plots GL2018-1 (control samples) and plots GL2018-4 (highest proportion of amended fly ash, 1.0 kg/m^2) to show the most significant variation of the application. Without fly ash application, spinach grow gradually from 6 cm (5th April) to 29.43 cm (5th May); with the application of 1.0 kg fly ash/m^2, spinach height reaches 34.93 cm at the end of the experiment period. Significant development of spinach height variation can be observed from 20th April where the gap showing spinach height between fly ash amended plant and non-fly ash amended plant clearly extended and stably rise until the end of the experiment period.

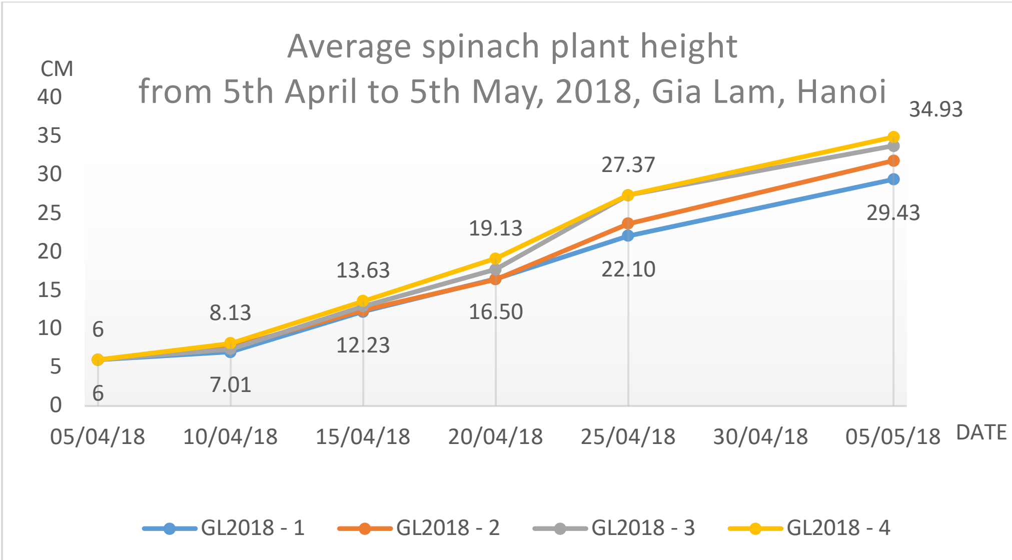


Figure 19. Average spinach plant height from 5th April to 5th May, 2018, Gia Lam, Hanoi

Number of spinach leaves counted in field experiment at Gia Lam, Hanoi is presented in figure 20. The amount of leaves is counted, include both matured leaves and baby leaves, fluctuate from start of the planting until 20th April. After that, the number of total leaves raise with the outstanding break of spinach plots GL2018-4. During the whole experiment, plots GL2018-2 leaves results are all slightly higher as compared with control plots GL2018-1, the upward shift of spinach plots GL2018-2 in the ending period is insufficient and resulted at the lowest.

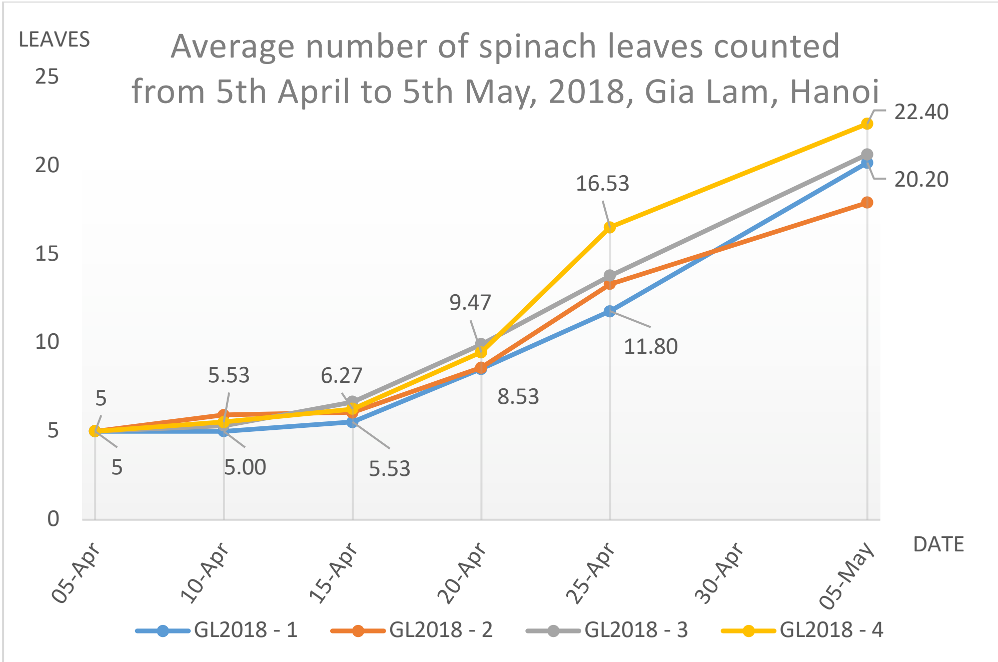


Figure 20. Average number of spinach leaves counted in 5th April to 5th May, 2018, Gia Lam, Hanoi

Average spinach root length was measured at the end of the experiment. The differences between average samples root length of different amended fly ash ratio ranges from 0.6 cm to 1.5 cm. Shortest average root length is spinach plots Gl2018-1 with only 12.87, while plots GL2018-4 have the highest average root length of 16.10 cm. With amended fly ash in cultivating soil, overall average root length increases as compared with control plant samples root length.

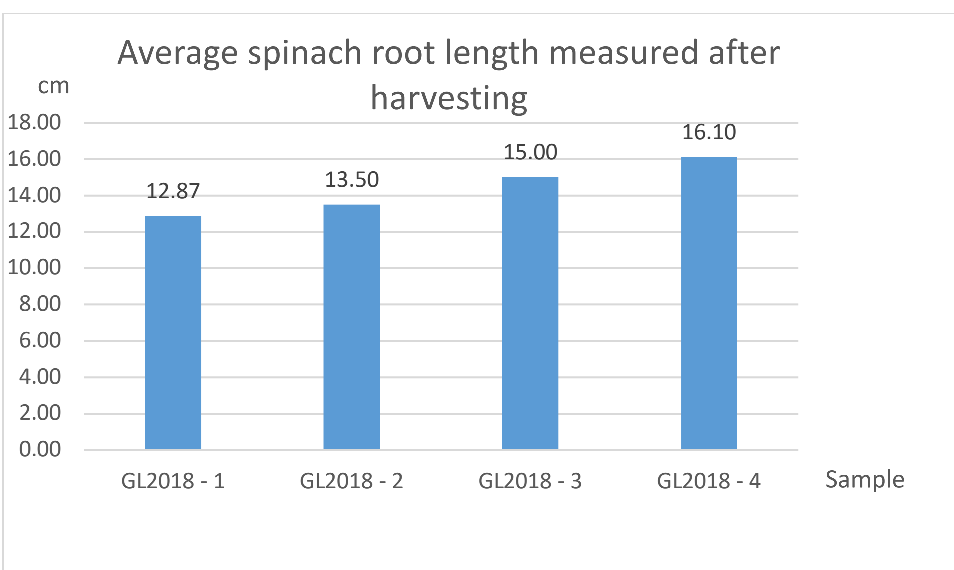


Figure 21. Average of spinach root length measured after harvesting

Figure 22 illustrate the weighted average spinach yield of each amended fly ash formulas. Spinaches with applied-fly ash grow heavier than non-applied fly ash spinaches. Spinach plots GL2018-1 weigh 2.536 kg/m^2, almost 1 kg lower than spinach in plots GL2018-4 with an average weigh of 3.397 kg/m^2. The significant upward trend of average spinach yield suggests significant increase of profit if fly ash is applied in vegetable horticulture.

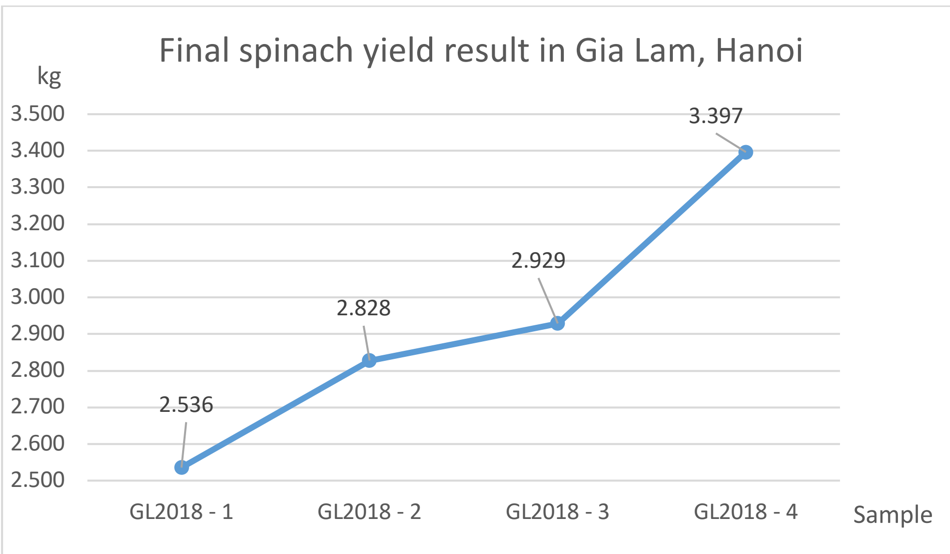


Figure 22. Final spinach yield result in Gia Lam, Hanoi

5 DISCUSSION

UEI Ltd. project aims to produce electricity by incinerating Phu Tho Province's municipal waste with advance technology, serving the purpose of environmental protection and safe/cost-effective energy generation. Circular economy concept is adopted into their principles and energy production as to reduce negative impact from linear economy, turning waste from one industry into raw material/energy for another and create a closed industrial loop that generate no waste (Ellenmacarthurfoundation.org., 2017). The project is also subjected to comply with national and local environmental policies and standards meeting the need of future development. The chosen technology for the project is Belgium Waterleau

Energize waste grate incinerator which is designed to specifically combust MSW with complex composition, high moisture and low calorific value. Combining Waterleau incinerator with other advanced technology such as flue gas purification system, sewage treatment Nano-filtration Membrane and bag house filter media, the design is considerably applicable for Vietnamese MSW composition. In additionally, the expected energy production capacity of the power plant is around 10 megawatts (MW) per hour, with the incinerator and boiler efficiency is more than 83% and the plant energy consumption is 18%, production energy is then recycled (UEI-Au Viet, 2017).

Turning waste to energy does not only benefit the local's environment but also its industry as well. As standard disposal price for waste disposal in Vietnam as according to Decision No. 798/QD-TTg of May 25, 2011, approving the program for investment in solid waste treatment during 2011-2020; Decision No. 322/QĐ – BXD of 6th April, 2012, by Ministry of Construction publishing construction investment and cost for municipal solid waste treatment and Decision No. 31/2014/QD-TTg dated May 05, 2014, on supporting mechanism for development of power generation projects using solid waste in Vietnam, electricity price for each kwh is 2.114 dong which equal to 0.1005 USD/kWh. Accordingly, the amount of energy production annually would reach 8 million USD (before tax). The utilization of fly ash would reduce the cost for waste treatment and make profit by selling electricity at the same time.

UEI-Au Viet cooperation planned approach of fly ash disposal would be using polymer treatment with quota of 0.03 polymer per tonne of fly ash; and with the price of polymer on the market of 110 million dong/tonne (about 4 800 USD/tonne), the cost for fly ash treatment will cost up to 719 000 USD per year alone. Economically benefit and improving Vietnam environment quality, Au Viet Company purposed to focus more on the agriculture application aspect presenting a more sustainable and environmental friendly way of utilizing fly ash accounting for its life cycle. However, there's a lack in the number of researches and experimentations on the application of fly ash in soil application and plant yield improvement limiting the actual use of fly ash-fertilizer in Vietnam (UEI-Au Viet, 2017).

5.1 Application of fly ash as soil ameliorant in Phu Tho Province

Addition of fly ash in soil samples show positive improvement in soil acidity and fertility which is also proven in studies and researches that describes fly ash ability to amend damaged soil (Capp, 1978, 339). The experiment carry out process is quite short and simple, not including sample analysis, soil sample collection and formulation was done in a short period of time (about 48 hours) by few individual, which is cost effective and not time consuming as seasonal farming. However, the lack in soil sample analysis raise questions on the affirmation of acquired results.

Measured pH in soil sample buffered with the application of fly ash. The fly ash used in the study have pH level of 10.68 there for it can buffer the acidic soil sample. The soil samples are mostly acidic with pH range from 3.65 to 4.18 in (controlled samples). Reacting with the lime in soil, all acidic soil sample shows increase in pH, particularly in Bang Luan Commune series sample where soil sample pH reach highest at 6.15. Soil pH determine the availability of essential nutrients in soil; and plants are not tolerant with the wide range of acidity in soil (Jauron, 2002). Therefore, adjusting soil pH is an important factor in remediating damaged soil.

Cation exchange capacity level represent the capacity of soil to hold exchangeable cations which in turn affect the ability to hold nutrient of soil. Organic matters acquire for high CEC level because negative charges are attached on their surface which draw in cation elements. Silt soil has the same mechanism, the nutrients element which have positive electric charges such as Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} will be attracted by the silt soil and remain in the soil. CEC level determine soil association with these nutrient; the more organic and silt soil available in the soil, the higher the CEC level. For instant, soils with a low level of CEC are more likely to develop deficiencies in K^{+}, Mg^{2+} and other cations. Study by Nalbantoğlu (2004, 377-381) stated that with the increase of fly ash in soil, the cation exchange capacity decreases. Similar study by Akbulut S. and Arasan S. (2010, 139-154) present the same conclusion. In the study case of Phu Tho soil sample, CEC in Bang Luan soil decreases when fly ash application increases. The changes are steady, with the addition of 5 kg FA/m^2 to soil sample, an average of 1.5 cmol/kg CEC is reduced (addition of 10 kg/m^2 ≈ reduction of 3 cmol/kg CEC, addition of 15 kg/m^2 ≈ reduction of 4.5 cmol/kg CEC). However, CEC results show in other three location alternate the conclusion as they present unstable declination in CEC level. Opposite to Bang Luan results, CEC level in Phu Ninh soil sample increases as correlate to control sample.

Irrational changes of Phu Ho and Te Le soil sample results might have caused by the lack of fly ash resident time in the soil. At normal soil treatment approach, where fly ash is applied straight to the cultivating field, these ashes carrying nutrients (such as Ca^{2+}, Mg^{2+}, Na^+ and K^+) and react with local plants/trees and soil. Yet, the differ of soil experiment in Phu Tho experiment and this theory approach leads to confusion in the data result. Hence, concentration of Mg^{2+} and Ca^{2+} in soil statistic in figure 12 surge with amended fly ash. The abundant of available cation in soil is quite low with only Mg^{2+} at around 10 - 16 meq /100g soil and Ca^{2+} at around 0.5 - 2.2 meq/100g soil. At proportion of 15 kg FA/m^2 soil, Mg^{2+} and Ca^{2+} content increase to 68.02 meq/100g and 8.03 meq/100g, accordingly. The increase in soil cation may originated from Ca and Mg content available in fly ash, which are soluble and can absorb water in soil to extract Ca^{2+} and Mg^{2+}. This vivid change of cation concentration in soil solution directly alter CEC level in soil. And with the increase of cation in soil, CEC level is presumed to increase, in which the analysis result shows contradiction.

The organic matter in soil provide nutrients such as N, P, K as supplements for plant/tree and soil organism; it can also improve soil structure and water holding capacity (HGCA Farm Walks, 2013). The amount of organic matter in the soil can present the study soil type. For example, soil with almost 50% clay may need 6% of organic matter (Nationwide, 2018). Data from figure 8 suggesting Bang Luan, Phu Ho, Phu Ninh soil samples are loamy soil while Te Le soil samples are sandy loamy soil. For loamy soil sample, percentage of fly ash in soil sample range from

0.008% to 0.025%; for sandy loamy soil sample, fly ash percentage range from 0.007% to 0.021%. Due to the small proportion between fly ash and soil sample, the amount of nutrient in the fly ash does not have significant effect on available nutrients in soil sample so changes between the samples nutrients values cannot be interpreted therefore there are no changes at all; the measure amounts of nutrients in this soil analysis are mostly the result of available nutrients in the soil. This theory can be used as a hypothesis or presumption for other found component in soil such as percentage of Fe (figure 14). 0.94% Fe is analysed from fly ash solution taking up a small portion in total amount of iron in the soil that cannot display clear changes.

Applying the same theory for data in figure 10 of soluble reactive phosphorus (SRP) and exchangeable potassium in soil sample, these figures should only represent the amount of SRP and exchange K in available soil. Utilize fly ash SRP and exchangeable K only adding a small percentage to the available soil. In addition, the amount of plant absorbs SRP and exchangeable K only account for small proportion of the total P and K in the soil solution. Approximately, exchangeable K only account for 1-2% of the total potassium in soil (Terragis, 2007). Unlike P and L content in soil, measure silicon content on soil sample slightly increases, apart from active silicon percentage of sample PH4, BL3, and BL4. Significant increase of Si% might be explained by the release of Si content in amended fly ash or potential error during analysis.

With climate experiences, water content in the soil might change positively and fly ash can improve soil porosity and increase water holding capacity in soil (Korcak RF, 1995, 107-130). Korcak study indicated that water retention capacity and soil porosity will improve if fly ash is applied to normal field soil. Hence figure 11 results shows slight reduction in water content. Soil water content is easily being alternate by the adding of dry ingredients, and in this case, is fly ash. Fly ash has a low content of only 1.63% so it would absorb the water in available in soil and reduce the soil humidity. Nonetheless, soil sample in this thesis study case did not experience climate in local area, which dismiss the environment effect such as rain water and temperature.

Each element of soil samples in Phu Tho was analysed only once without necessary repetition due to financial inadequacy. Accordingly, there was only one experiment for each element to be analysed leading to relatively uncertainties of the end results. The account for heavy metals (Al, Mn, Cu, Zn, B, As, Pb, Cd) in this thesis study is quite untrustworthy and should not be used as references to indicate fly ash behaviour in soil. Though other studies have indicated fly ash ability as soil remediation to prevent toxic effects of Al^{3+} and Mn^{2+} and other metallic ions by neutralizing the soil acidity (Fail and Wochok, 1977, 473-484).

An overall unstable observation is presented in the result of soil sample with fly ash application analysis in Phu Tho Province. With the content of the study is not assertively focused on only a few criterial that most represent soil health (such as soil pH, aluminium level, water content and holding capacity) but spread out in 22 different factor. This method of approaching soil sample study lowering result accuracy. For each research sample, there should be at least 3 to 5 repetition to reduce errors and false data in the result help accomplishing adequate study data. In this study case of soil study in Phu Tho Province, each sample element was measured once that follows Vietnam chemical analysis standard protocol TCVN 7131:2002 for soil.

Interstate Technology and Regulatory Council (ITRC) managed by the Environmental Council of the States in the USA has published Technical and Regulatory Guidance of soil Incremental Sampling Methodology describes sampling and processing protocol estimate of mean contaminant concentrations in a volume of soil targeted for sampling. This guidance point out that a single sample or even several discrete samples do not well represent the study subject due to soil heterogeneity (ITRC, 2012, 19-20). Incremental sampling methodology also publish data of representative samples of soil which is combined, processed and subsampled by 30 to 100 increment samples. For data to represent characteristic and condition of the region/site, the group of collected samples need to accurately reflect the condition of the site. Soil components (especially pollutants) are unevenly distributed within a site and can be easily washed away external factor such as rain (IAEA, 2004, 1-6). Hence, Phu Tho soil sample results are quite unreliable even though fly ash behaviour in soil sample regarding soil pH, Ca^{2+}, Mg^{2+}, water content (and so on) are still in favour referring the literature reviews.

Sudden changes in the diagrams and data errors might have occurred during Phu Tho soil samples analysing processes: sample collection, mixing of fly ash and soil, and the analysis. The samples were collected bare hand without proper protection. Sampling equipment was not sterilized and clean during the process of digging and exacting different soil. When the soil was removed from the ground by the augers, angled spatula was used to separate the soil from the augers and into the zip bag. This process could have been affected by external factor such as excess water or remained soil/substances left on the equipment gotten into the new sample and alter the result. During the mixing of fly ash and soil, the weighting process was done on available/used paper of other experiment in the institution. The papers already contain a very small amount of soil stuck on the surface of the paper, though the dusting of the paper beforehand does remove a certain amount of excess soil from the paper, it was not certified to be completely clean and may ad unnecessary element into the samples. Not to mentioned the error that might occurred during soil sample weighing performance. The soil weighting, fly ash weighting and sample packing was done by 3 workers with each perform a specific task. The soil sample then kept in zip bags and handover to the Northern Mountainous Agriculture and Forestry Science Institute to mix and analyse the samples. The actual process of sample analysis was observed and monitored by the institute staff following Vietnam sampling protocol. However, there are still possibility of error occur during the analysis process, which is not accessible and might unlikely to happen.

The experiment process is not relatively advisable since applied fly ash does not bear a certain amount of time in the regular soil with actual conflict weather condition before being sent to analysis. Collected soil samples were mixed with fly ash for a period of 10 days before analysis processes which partially affect fly ash behaviour in soil samples and, as a result, present undesirable results. Suggested process for analysing soil sample with the application of fly ash is to analyse the result soil after the cultivation period of fly ash treatment. After being spread into the planting area, fly ash would filtrated to the ground and react with the local environment soil. This would allow fly ash to alter soil condition and the analysis result can be observed more clearly compared to the mixing method. Since amended fly ash onto cultivating soil penetration ability depends on the physical characteristic of the fly ash, it and can be washed through the surface soil layers (humus, organic matter and topsoil layers). This results in uncertainties of acquiring soil samples at 30 – 50 cm soil level from the surface which the calculation of required fly ash is based on.

Additionally, part of the nutrients from the fly ash will be absorbed by local plant substantially so the amount of nutrient found in later sample analysis would lessen in the case of soil study after the planting period as compared to study of soil before the application of fly ash (which analysis experiment only by mixing the ash into collected soil sample). The type of local plant would strongly affect the behaviour and changes make by fly ash in the soil due to the fact that plant nutrient absorption differ depends on individual plant type. For example, spinach accumulated a high content of Mn and Zn and low concentration of Cu and Pb in their tissues (Intawongse et al., 2006, 36-48).

The fly ash application in cultivating soil is not only benefiting the ecology of soil and improving plant yield, but also reducing disposal waste cost and profiting from electricity generation. Unutilised fly ash landfilling disposal method allows serious chemical leaching threatening environmental and human health. With the utilization method suggested by Au Viet Company, the application of fly ash in soil would not cause adverse effect on the local soil. Additionally, commercialized fly ash with market profit is double-cost effective as it also reduces fly ash disposal cost which account for 719 000 USD per year alone.

5.2 Application of fly ash in improving Spinacia oleracea yield and quality in Gia Lam, Hanoi

Spinach result shows an overall yield and quality improvement with the increase of fly ash in the soil. The more fly ash is used on the soil, the bigger the spinach grow as compared to the control plant plots. The different between spinach plant with different dosage of fly ash application spread further following the timeline. If the experiment continues without harvesting, the different of the line charts would appear more significant. There was a gradual growth in spinach height for the first 15 days, the breakthrough of soil amended fly ash occurs especially from 20th April (after 15 days of planting) where a clear gap between control sample plot and fly ash amended plots was observed. Same observation can be seen from the line chart describe number of spinach leaves which is very important because spinach is a vegetable with leaves represent 100% of its yield.

Acquired result from spinach planting experiment in Gia Lam, Hanoi recognised a comprehensive yield improvement. With 0.5 kg of fly ash used on one square meter, the average spinach yield increase from 2.536 kg to 2.828 kg per plot, equivalents to an increase of 11.51% of yield. Corresponding, at proportion of 0.75 kg FA/m^2 and 1.0 kg FA/m^2 there are increases in yield of 15.50% and 33.95%, accordingly. The abnormal increase in spinach yield raise concerns on the dosage of amended fly ash since ended product (spinach) did not experience special analysis to ensure available toxicity remain at safety level for human consumption. Another important signature of fly ash application in spinach is the inhabitation of pest and diseases in plant. Visual observation of pest activity in plant noted in Spinach Field Experiment Diary shows strong pest resistance. Unfortunately, pest resistant ability of fly ash amended spinach was not detailed measure due to predicament.

Application of fly ash in agriculture is not widely adapted since farmer and product consumer still have doubts on the assurance of the product itself. Visually, fly ash is a type of ash resulted from coal combustion or burn of other type of material which might appears unhealthy for the human body. There are few studies on the allowed fly ash application to the soil and the level of toxicants that are present in the plant/crop product. These studies are essential to build trust in the commercial market since food health relate directly to human's. However, in this report, the planted spinach was not analysis for toxicant identification and neither was the cultivated soil. Therefore, the study experiment for fly ash application in spinach is just partly completed with the amendment of fly ash in different aiding level. Study of actual nutrients and toxicant component in the final products, including the improvement of the soil, would complete the project aim and enhance the applicability of the application. The lack of liability in this case study of spinach was to be supported by the soil sample study in Phu Tho. However, due to the unstable data received, Phu Tho sample result should not be considered prove study for the spinach growth experiment regarding human health qualifications.

Circular No. 07/2013/TT-BNNPTNT (January 22, 2013) issued national technical regulation on fresh vegetable, fruit and tea – conditions for ensuring food safety in production and preparation. This Circular provided a specific guideline for the limitation of a few heavy metals in cultivating soil, which includes Arsenic (12 mg/kg), Cadmiun (2mg/kg), Lead (70 mg/kg), Copper (50 mg/kg), and Zinc (200 mg/kg). Hence, The Ministry of Agriculture and Rural Development of Vietnam is still at complement and finalization stage in publishing standard guildlines on technical standards and regulations as well as technical guidance on the use of ash in agriculture according to Decision No. 452/QD-TTg dated April 12, 2017 (ILS, 2017). Therefore, there is yet standard or guideline of fly ash agriculture utilization in Vietnam, so studies with the purpose of using/applying fly ash in Vietnam soil should based on international available documents referring the subject.

6 CONCLUSION

Fly ash can be used as soil ameliorant and potential nutrient supplement for plant productions. The utilization of fly ash brings environmental and economical benefit to the environment and Au Viet cooperated Company by applying circular economy concept in fly ash utilization. This contributes considerable profits to the local improving local govern industry management by taking care of solid waste problem and improving agricultural estate. With amended fly ash to soil samples, soil characteristic and spinach yield improvement can be recognized. Despite possible uncertainties and confusions in a few Phu Tho soil sample data result, clear improvement of soil pH, which is very important as Vietnam soil is strongly acidic inhabiting plant growth, is observed. Strong development of spinach yield is measured showing increase in plant production and pest resistant.

The study of fly ash behaviour in Phu Tho soil sample and spinach yield improvement in fly ash was planned to support each other in theory and promoting the use of fly ash in agriculture. However, Phu Tho soil sample result shows confusions and errors which can be explained by two major reasons, study approach and lack of sample repetition. The study approach for Phu Tho soil sample is to analyse mixtures of fly ash and local soil instead of analysing field amended fly ash soil samples. This prohibits fly ash alteration ability in soil and can lead to false data. While the analysis samples are calibrated and measure once without repetition makes the result unreliable.

Reasonable proposal approach for future study of fly ash application in agriculture is to collaborating soil sample analysis with vegetable/crop plant analysis after fly ash amended cultivating period to identify soil and quality and toxicity level studies. Additionally, studies of fly ash legislation and regulation of metal toxicity tolerant in soil and vegetable/crop plant are required whenever fly ash are applied in agriculture soil. The study case of amended fly ash in Vietnam agriculture soil experienced difficulties in identify allowed amended fly ash in soil due to the lack in Vietnam legislation regarding the subject. Decision No. 452/QD-TTg suggesting future standards and guidelines for fly ash application in specific regions in Vietnam. These guidelines will be suitable for similar future studies of fly ash utilizations.

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APPENDICES

APPENDIX I. Sample collection details

No.	**Location**	**Elevation above sea level** *(m)*	**Sample collection time**	**Plant type**	**Soil type**	**Sample**	**Sample mark**	**Note**
1	Phu Ninh Commune, Phu Ninh District	220	10:30 (23/03)	Eucalyptus (paper material)	Loam	4	PN1-4	Low nutrient soil
2	Te Le Commune, Tam Nong District	220	13:30 (23/03)	Rhizoma Belamcanda (medicinal plant)	Sandy loam	4	TL1-4	River bank soil; sample TL2 near underdeveloped plant
3	Phu Ho Commune	230	16:00 (23/03)	Camellia sinensis (tea plant)	Loam	4	PH1-4	Perennial mountainous camellia sinensis culture
47	Bang Luan Commune, Doan Hung District	250	08:30 (24/03)	Citrus maxima (grapefruit)	Loam	4	BL1-4	Perennial citrus maxima culture

APPENDIX II. Soil sample and bio fly ash application

No.	Sample mark	Soil type	Bulk density *(g/cm3)*	Depth *(cm)*	Bio fly ash ratio *(kg/m2)*	Soil per sample *(g)*	Bio fly ash per 500g sample *(g)*	Note
1	PN1	Loam	1.2	50		500.000		Control
2	PN2				5	495.868	4.132	
3	PN3				10	491.803	8.197	
4	PN4				15	487.805	12.195	
5	TL1	Sandy loam	1.4	30		500.000		Control
6	TL2				5	496.454	3.546	
7	TL3				10	492.958	7.042	Underdeveloped plant
8	TL4				15	489.510	10.490	
9	PH1	Loam	1.2	50		500.000		Control
10	PH2				5	495.868	4.132	
11	PH3				10	491.803	8.197	
12	PH4				15	487.805	12.195	
13	BL1	Loam	1.2	50		500.000		Control
14	BL2				5	495.868	4.132	
15	BL3				10	491.803	8.197	
16	BL4				15	487.805	12.195	

APPENDIX III. Analysis result of subject study fly ash

VIỆN KHKT NÔNG LÂM NGHIỆP MIỀN NÚI PHÍA BẮC
PHÒNG PT ĐẤT VÀ CL NÔNG SẢN
VILAS 654

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Số 89/KQPT-MNPB

Phú Thọ, ngày 15 tháng 8 năm 2017

PHIẾU TRẢ KẾT QUẢ

Đơn vị yêu cầu: Nguyễn Quang Hưng – Công ty Cổ phần tiến bộ quốc tế(AIC)
Địa chỉ: Số 54 Liễu Giai, Ba Đình, Hà Nội.
Điện thoại: 0902110357
Tên mẫu: Mẫu Bio Fly Ash
Ngày nhập mẫu: 02/08/2017

Số lượng mẫu: 01 mẫu
Trạng thái mẫu: Bảo quản trong túi PE
Ngày thực hiện 04/8/2017

Số TT	Chỉ tiêu thử nghiệm																
	pH	W (%)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (%)	Cu (ppm)	Zn (ppm)	Mn (ppm)	Pb (ppm)	As (ppm)	Al (ppm)	Si (%)	Bo (ppm)	Độ dẫn điện (µS/cm)
	10,68	1.63	0,196	0,107	19,39	0,11	0,256	0,94	9,7	75,55	59,3	14,37	7,53	27,16	0,18	12,03	2,81

Trưởng Phòng

Cao Hoàng

Người lập bảng

Trần Lệ Thu

BM-TT-5.10-02

1. Phiếu kết quả này chỉ có giá trị đối với mẫu thử nghiệm.
2. Không được trích sao một phần kết quả này nếu không được sự đồng ý của lãnh đạo PTN.
3. Tên đơn vị yêu cầu và tên mẫu được ghi theo yêu cầu của khách hàng.

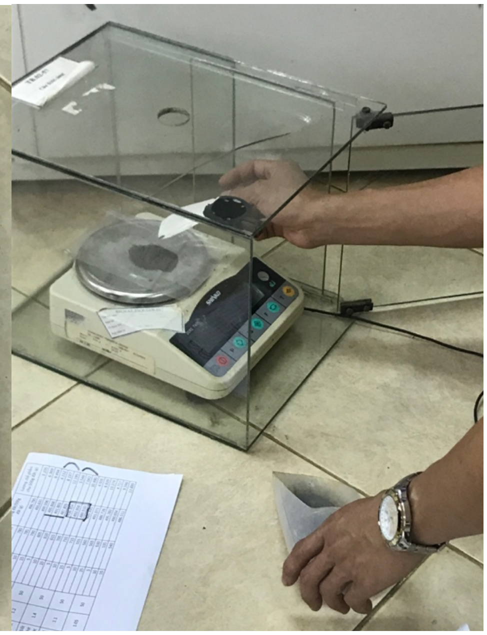
APPENDIX IV. Soil sample analysis results from Northern Mountainous Agriculture and Forestry Science Institute

TT	Kí hiệu mẫu	Chỉ tiêu phân tích										
		pH (KCl)	CEC (Cmol/kg)	OM (%)	N (%)	P (%)	K (%)	Pdt (mg/100 g đất)	Kdt (mg/100 g đất)	W (%)	Ca^{2+} (meq/ 100g đất)	Mg^{2+} (meq/ 100g đất)
1	BL1	3,65	8,64	2,87	0,392	0,069	0,040	28,68	18,13	19,45	2,10	10,03
2	BL2	4,85	6,78	2,63	0,392	0,049	0,069	23,31	57,44	17,77	4,64	32,39
3	BL3	5,50	5,82	3,01	0,476	0,052	0,067	39,99	32,84	19,86	6,21	53,11
4	BL4	6,15	4,29	3,25	0,644	0,066	0,068	38,50	35,77	19,25	8,03	68,02
5	PH1	3,69	9,22	3,62	0,392	0,002	0,056	2,53	7,31	14,72	0,97	3,68
6	PH2	3,92	6,78	2,22	0,224	0,012	0,082	6,68	11,73	14,11	2,19	13,08
7	PH3	4,17	7,49	2,45	0,364	0,001	0,086	11,54	11,00	13,77	3,53	25,28
8	PH4	4,13	9,73	2,20	0,420	0,008	0,071	13,46	12,72	15,13	4,73	35,39
9	PN1	3,72	6,98	2,28	0,448	0,006	0,053	1,92	3,37	13,04	0,51	3,22
10	PN2	4,12	9,98	3,25	0,336	0,010	0,062	24,16	5,58	13,68	2,79	15,92
11	PN3	4,92	9,66	3,96	0,364	0,012	0,061	13,19	13,21	12,53	5,49	44,71
12	PN4	4,77	9,02	3,42	0,616	0,023	0,057	16,64	8,78	12,49	4,97	37,59
13	TL1	4,18	5,44	1,50	0,252	0,001	0,333	18,62	12,72	24,66	2,11	15,67
14	TL2	5,34	10,24	1,88	0,308	0,001	0,290	31,68	11,24	24,88	3,09	23,46
15	TL3	5,19	4,22	2,12	0,336	0,002	0,308	28,58	11,00	23,86	3,60	25,45
16	TL4	5,55	5,70	1.67	0,392	0,031	0,289	21,39	8,78	23,93	3,29	23,45

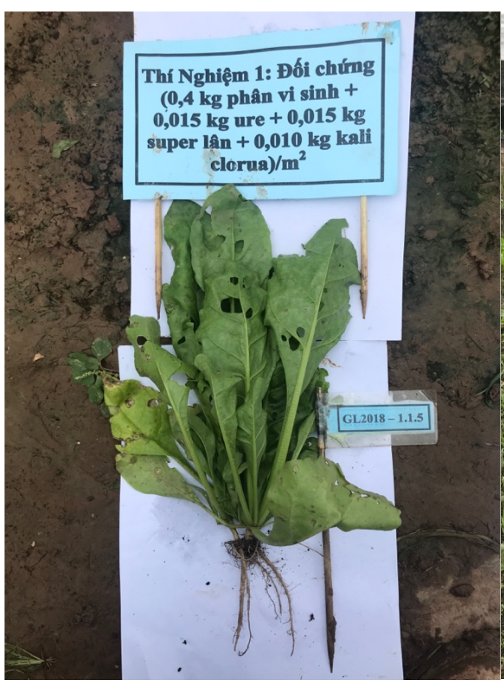
TT	Kí hiệu mẫu	Chỉ tiêu phân tích										
		Si_{hh} (%)	Fe (%)	Al^{3+} (cmol/kg)	Mn (ppm)	B (ppm)	Si (%)	As (ppm)	Cd (ppm)	Pb (ppm)	Cu (ppm)	Zn (ppm)
1	BL1	0,124	6,50	1,1	94,30	1,37	49,43	1,96	0,052	2,79	53,30	67,00
2	BL2	0,128	5,68	0,3	99,30	1,25	49,81	2,31	0,053	1,2	39,00	57,20
3	BL3	0,235	6,10	0,1	119,70	1,63	56,34	2,48	0,066	2,63	56,90	79,70
4	BL4	0,262	5,90	0,2	166,40	1.19	57,96	2,52	0,093	3,21	51,10	53,90
5	PH1	0,096	4,95	1,8	83,20	0,98	60,12	1,37	0,026	3,33	20,90	41,50
6	PH2	0,112	4,21	1,2	94,40	0,87	61,18	1,53	0,045	2,90	27,20	45,80
7	PH3	0,120	4,53	0,9	102,60	1,02	65,58	1,72	0,025	2,13	31,50	76,40
8	PH4	0,301	4,32	0,3	81,60	1,35	67,92	2,27	0,025	1,90	28,50	46,50
9	PN1	0,150	4,20	1,9	68,00	4,68	56,16	1,14	0,039	2,67	16,00	47,90
10	PN2	0,152	4,13	1,0	57,40	22,95	57,77	1,81	0,021	1,88	14,40	48,80
11	PN3	0,165	3,91	0,6	62,60	3,15	58,87	1,73	0,037	1,36	23,55	52,20
12	PN4	0,179	3,96	0,3	63,70	4,22	67,22	1,50	0,049	1,56	18,80	38,30
13	TL1	0,238	2,01	0,4	235,70	1,43	76,95	3,74	0,027	1,74	7,00	57,50
14	TL2	0,248	1,64	0,1	145,70	6,59	77,56	4,01	0,025	1,68	3,10	29,40
15	TL3	0,250	1,71	0,2	200,50	5,22	77,90	3,80	0,038	2,11	8,10	45,20
16	TL4	0,272	1,69	0,1	185,20	7,16	78,08	4,68	0,027	1,96	4,00	35,40

APPENDIX V. Images of Phu Tho province soil sampling process


GF-2000
Max2100g Min0.5g e=0.1g d=0.01g
500.00 g
ON/OFF
CAL
SAMPLE
PRINT
MODE
RE-ZERO



APPENDIX VI. Images of planting spinach in Gia Lam, Hanoi



APPENDIX VII. Spinach planting Field Experiment Diary

CÔNG TY CỔ PHẦN TÀI NGUYÊN VÀ MÔI TRƯỜNG ÂU VIỆT

AU VIET RESOURCE AND ENVIRONMENT JOINT STOCK COMPANY

NHẬT KÝ
THÍ NGHIỆM ĐỒNG RUỘNG
FIELD EXPERIMENT DIARY

Tên thí nghiệm: *"Nghiên cứu ảnh hưởng của Bio Flyash đến sinh trưởng phát triển của cây cải bó xôi vụ xuân hè 2018 tại Gia Lâm,Hà Nội".*

Experiment: *"Investigate the effect of bio fly ash on spinach growth during 2018 Spring-Summer cultivating season in Gia Lam, Hanoi".*

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Giáo viên hướng dẫn 2 (supervisor 2): ThS (Msc) Nguyễn Quang Hưng

Hà Nội, 2018

EXPERIMENT CONTENT

Subject: Spinach (Spinacia oleracea)

Time period: 02/04/2018 – 20/05/2018

Location: Experimentalize garden in Hanoi University of Agriculture, Gia Lam, Hanoi

Experiment content:

- Apply 4 triplicate bio fly ash formulas samples (with 5 plant date for each formula)
- Pot area: 1.2m^2/sample (average 30 plant/pot)
- Density: 15 x 20 cm
- Test formula:
  + Formula 1: Control: 0.4 kg manual, 0.015 kg urea + 0.015 kg superphosphate + 0.010 kg potassium chloride, no fly ash application
  + Formula 2: 0.5 kg bio fly ash/m^2
  + Formula 2: 0.75 kg bio fly ash/m^2
  + Formula 2: 1.0 kg bio fly ash/m^2
- Care regime and watering recommended

Plant growth, yield and quality

- Plant growth: plant height, root length, number of leaves, leaves superficies, leaves colour, pest intrusion, mortality rate
- Yield and quality: plant yield/m^2, leaf weight, sensible evaluation

❖ Average plant height (before plantation): 6-7 *(cm)*

❖ Average number of leaves (before plantation: 5 *(leaves/plant)*

❖ Average root length of plant (before plantation): 4 *(cm)*

- Experiment formula mark: **GL2018 – 1.2.3**

  Where as: **GL2018**: Gia Lam 2018; **1**: Formula 1; **2**: Second repeat; **3**: Sample 3

- Thời gian đo đếm (Measuring time):…………………………………
- Điều kiện khí hậu, thời tiết (Wether condition): ……………………..
- Người thực hiện (Observer):…………………………………………

STT No.	**Công thức Formula**	**Chiều cao cây Plant height** *(cm)*	**Số lá/cây Leaves/ plant** *(lá)*	**Màu sắc lá Leaves colour**	**Chỉ tiêu sâu, bệnh hại Pest and Disease**		**Chỉ tiêu khác Other**	**Ghi chú Note**
					Sâu hại Pest	**Bệnh hại Disease**		
1	GL2018 – 1.1.1							
2	GL2018 – 1.1.2							
3	GL2018 – 1.1.3							
4	GL2018 – 1.1.4							
5	GL2018 – 1.1.5							
6	GL2018 – 2.1.1							
7	GL2018 – 2.1.2							
8	GL2018 – 2.1.3							
9	GL2018 – 2.1.4							
10	GL2018 – 2.1.5							
11	GL2018 – 3.1.1							
12	GL2018 – 3.1.2							
13	GL2018 – 3.1.3							
14	GL2018 – 3.1.4							
15	GL2018 – 3.1.5							
16	GL2018 – 4.1.1							
17	GL2018 – 4.1.2							
18	GL2018 – 4.1.3							
19	GL2018 – 4.1.4							
20	GL2018 – 4.1.5							
21	GL2018 – 1.2.1							
22	GL2018 – 1.2.2							
23	GL2018 – 1.2.3							
24	GL2018 – 1.2.4							

STT No.	Công thức Formula	Chiều cao cây Plant height *(cm)*	Số lá/cây Leaves/ plant *(lá)*	Màu sắc lá Leaves colour	Chỉ tiêu sâu, bệnh hại Pest and Disease		Chỉ tiêu khác Other	Ghi chú Note
					Sâu hại Pest	Bệnh hại Disease		
25	GL2018 – 1.2.5							
26	GL2018 – 2.2.1							
27	GL2018 – 2.2.2							
28	GL2018 – 2.2.3							
29	GL2018 – 2.2.4							
30	GL2018 – 2.2.5							
31	GL2018 – 3.2.1							
32	GL2018 – 3.2.2							
33	GL2018 – 3.2.3							
34	GL2018 – 3.2.4							
35	GL2018 – 3.2.5							
36	GL2018 – 4.2.1							
37	GL2018 – 4.2.2							
38	GL2018 – 4.2.3							
39	GL2018 – 4.2.4							
40	GL2018 – 4.2.5							
41	GL2018 – 1.3.1							
42	GL2018 – 1.3.2							
43	GL2018 – 1.3.3							
44	GL2018 – 1.3.4							
45	GL2018 – 1.3.5							
46	GL2018 – 2.3.1							
47	GL2018 – 2.3.2							
48	GL2018 – 2.3.3							
49	GL2018 – 2.3.4							
50	GL2018 – 2.3.5							
51	GL2018 – 3.3.1							

STT No.	Công thức Formula	Chiều cao cây Plant height *(cm)*	Số lá/cây Leaves/ plant *(lá)*	Màu sắc lá Leaves colour	Chỉ tiêu sâu, bệnh hại Pest and Disease		Chỉ tiêu khác Other	Ghi chú Note
					Sâu hại Pest	Bệnh hại Disease		
52	GL2018 – 3.3.2							
53	GL2018 – 3.3.3							
54	GL2018 – 3.3.4							
55	GL2018 – 3.3.5							
56	GL2018 – 4.3.1							
57	GL2018 – 4.3.2							
58	GL2018 – 4.3.3							
59	GL2018 – 4.3.4							
60	GL2018 – 4.3.5							