APPROPRIATE COMPOSITION OF POWER PLANT WASTES FOR PREPARATION OF FIRED PLANTING MATERIALS

Kessaraporn Prasithichokekul[1], Sunanta Wangkarn[1], Sukdipown Thiansem[2]
Ponlayuth Sooksamiti[3], Orn-anong Arquero[1,*]

[1]Department of Chemistry, Faculty of Science, Chiang Mai University
Chiang Mai 50200 Thailand.
[2]Department of Industrial Chemistry, Faculty of Science, Chiang Mai University
Chiang Mai 50200 Thailand.
[3]Primary Industry and Mine Office Region 3
Chiang Mai , 50200 Thailand.

ABSTRACT

Fired planting material is presently very popular, because it has the special characteristics of light weight, low density and can be reused. Preparation of fired planting materials from bottom ash, flue gas desulfurization (FGD) gypsum which are residues from Mae Moh power plant in Lampang province mixed with paddy clay and sawdust was studied. Various formulae of planting materials were prepared by different ratios between bottom ash, FGD gypsum and paddy clay with different compositions of sawdust added, and different temperature of oxidation firing at 600, 700, 800 and 850 °C. It can be concluded that the appropriate composition for planting material is 22% of bottom ash, 7% of FGD gypsum and 45% of paddy clay with 26% of sawdust added. The best oxidation firing must be at least 850 °C for 30 minutes, with increasing rate of 3 °C/minute from room temperature. This planting material was not slake when soaked in water. It has 50% water absorption, pH 6.43, density 1.21 g/cm^3 and cation exchange capacity 8.9 meq/100g. It is shown that this produced planting material has high water absorption, slightly acidic pH value, light weight and rather high cation exchange capacity. Furthermore, this planting material has good characteristic from high quality unslaking which resulted from soaking it in water for 30 days.

KEYWORDS: Bottom ash, FGD gypsum, Paddy clay, Sawdust, Cation exchange capacity, Planting material, Bulk density, Water absorption

1. INTRODUCTION

The Mae Moh power plant in Lampang is a lignite coal fired thermal power plant. The production of power through combustion produces a huge amount of waste. Virtually every economical use of coal is affected by the amount and variety of waste products. Wastes in coal can be the source of deleterious pollutants and corrosive elements, but it can also be a source of useful by-products. Bottom ash-a dark gray, porous, sand-like granular material, can be used as a low-cost replacement for more expensive sand in the ceramic industry [1]. The principle constituents of bottom ash are carbon and heavy metals. Various chemical elements are present. Many elements in bottom ash such as Ca, Fe, Mg and K are essential for plant nutrition [2]. Bottom ash still appears to be an acceptable soil amendment [3].

In addition to laboratory green houses and experimental fields, bottom ash has potential as an agronomic soil additive that will not be detrimental to soil, crops or the environment [4]. Considerable amounts of FGD gypsum are generated when S is recovered from the burning of coal at electricity generating plants to meet Clean Air Standards. Beneficial agricultural uses of FGD gypsum include application as amendments to soil to improve the physical properties of soil [5, 6, 7].

* Corresponding author. Tel: 66-53-943341, Fax: 66-53-892277
E-mail: orpanyo@chiangmai.ac.th, noi2495@hotmail.com

At present, planting materials are important for many plants grown in containers [8]. The use of different waste materials such as pine bark, coconut fiber, peat, sand, rice hulls, perlite and vermiculite depends almost entirely on soil quality [9, 10, 11]. There are many waste materials used for the production of planting materials. Examples include almond shell waste [12], prune waste [13], pine bark, coconut fiber and sewage sludge [14]. This study focuses on the reuse of waste residues (bottom ash and FGD gypsum) mixed with paddy clay as novel planting materials. Low-cost residues are used to produce high value products.

2. MATERIALS AND METHODS

Three raw materials were dried and crushed to different sizes (bottom ash 100 mesh, FGD gypsum 100 mesh and paddy clay 80 mesh). These three solid wastes (bottom ash, FGD gypsum and paddy clay) were mixed in different proportions to produce mixtures whose compositions correspond to the open circles of the ternary diagram (Fig. 1). These samples were combined with different percentages of sawdust. Raw materials for production of planting materials were fired in a half cubic meter furnace, using liquid petroleum gas (LPG) as a fuel. The theoretical demand for thermal energy for firing from 25 °C to 850 °C equals to 924 kJ/kg. Initially, all samples were dried at 100 °C. Then, they were fired at various temperatures (600, 700, 800 and 850 °C). Finally, the physical and chemical properties of the fired samples were measured. The physical and chemical properties, such as slake, water absorption, density, pH and cation exchange capacity (CEC) [15] were measured. The chemical composition of waste materials used as feedstocks and products produced were obtained by X-ray fluorescence spectrometry (XRF). Material compositions were analyzed on a Phillips MagiX PRO PW 2400 Sequential X-ray Spectrometer (wavelength dispersive spectrometer) using Rhodium (Rh) tube. The mineralogical compositions of materials and product were obtained by X-ray diffractometer (XRD) patterns from randomly oriented powder mounts using Cu K∝ radiation. Then, Scanning Electron Microscopy (SEM) was used to determine the morphology of the bottom ash.

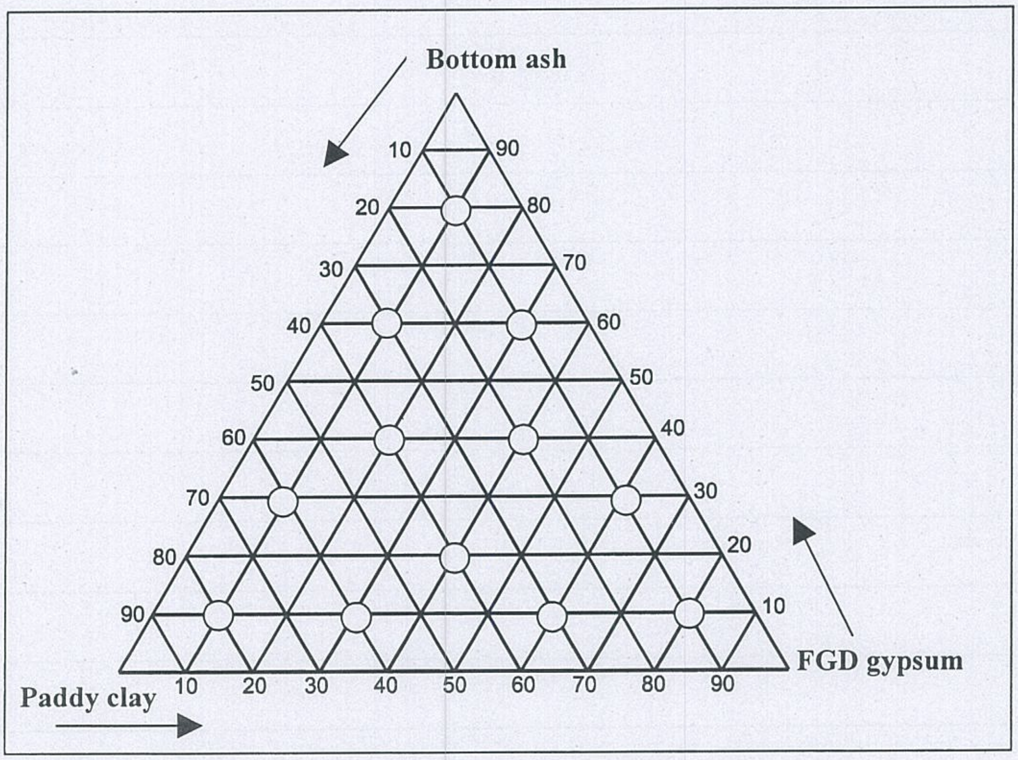


Figure 1. Three-dimensional diagram for generate the formulas of planting materials

3. RESULTS AND DISCUSSION

The chemical compositions of the bottom ash, paddy clay and FGD gypsum were measured using XRF as shown in Table 1. These XRF results (Table 1) were in agreement with the mineralogical compositions as determined by XRD (Fig. 2). As illustrated in Table 1, it indicated that major constituents of traditional planting material were silicon (Si), aluminium (Al), calcium (Ca), iron (Fe), potassium (K), magnesium (Mg), phosphorous (P), manganese (Mn), sodium (Na) and titanium (Ti). These are typically constituents accounting for about 95% of the mass of the traditional planting material. It has been documented that P, K, Ca and Mg are essential plant nutrients while Fe, Mn and Ba are only minor nutrients of plant [17, 18]. These elements were also found in these planting materials as given in Table 1. According to Fig. 3, the scanning electron microscopy showed that the largest fraction of bottom ash consisted of hollow spheres. At higher size ranges, porous sponge-like particles were detected. Therefore, it is suggested that bottom ash could be used as one type of nutrient adsorbent. For paddy clay, it is plasticity and high cation exchange capacity value.

Table 1. Chemical composition of solid wastes from Mae Moh power plant

Compound	Raw materials			Products	
	Bottom ash	FGD gypsum	Paddy clay	Planting material	Hydroton
macro-elements (wt%)					
SiO_2	37.82	0.87	64.13	49.74	59.68
Al_2O_3	30.83	0.69	19.50	14.47	17.16
CaO^{**}	9.44	23.68	0.63	12.59	3.65
$Fe_2O_3^{*}$	7.81	0.16	6.10	5.84	12.35
K_2O^{**}	2.07	nd	2.49	1.99	2.41
MgO^{**}	1.23	0.14	1.41	0.90	1.56
$P_2O_5^{**}$	-	-	0.09	0.07	0.19
MnO^{*}	0.06	nd	0.13	0.08	0.14
Na_2O	2.71	0.22	0.10	0.32	0.50
SO_3^{**}	2.03	64.92	-	-	-
TiO_2	0.36	nd	1.07	0.54	1.49
LOI.	5.41	9.26	4.21	14.03	0.00
micro-elements (ppm)					
Ba*	800.00	nd	1072.52	1324.35	725.93
V	110.86	2.91	187.11	28.289	188.52
Cr	57.56	2.93	102.56	97.68	278.48
Ni	21.98	5.44	80.74	53.65	73.20
Cu*	43.72	8.83	-	-	-
Zn*	178.54	nd	-	-	-

*nd = not detectable, - = not detect, ** = major nutrient of plant, * = minor nutrient of plant,*

*** and * refer from reference [17, 18]*

Upon heating, the pore structure of planting material changes. When the FGD gypsum ($CaSO_4.2H_2O$) was heated at temperature 150, 200 and 400 °C it changed from gypsum ($CaSO_4.2H_2O$) to hemihydrate ($CaSO_4.1/2H_2O$), more spaces anhydrite III ($CaSO_4$ III), more spaces anhydrite II ($CaSO_4$ II) and anhydrite I ($CaSO_4$ I), respectively. For paddy clay, the following changes were observed: water loss at 100 °C, combustion of organic matters at 200 °C, a change from α–quartz to β-quartz at 575 °C and decomposition of sodium carbonate at 600-850 °C. According to the changes above, the generated gases inside the hot glowing body, such as oxygen, hydrogen, carbon dioxide and carbon monoxide gases, caused the porous structure to be generated. Every formulation of planting material fired to 850 °C did not slake when submerged in water. High water absorption and low density depend on the percent weight of FGD gypsum but the high ratio of FGD gypsum results in a low CEC value.

Table 2. Physical and chemical properties of bottom ash-FGD gypsum-paddy clay based mixtures with sawdust, materials fired at 850 °C at rate 3 °C/minute.

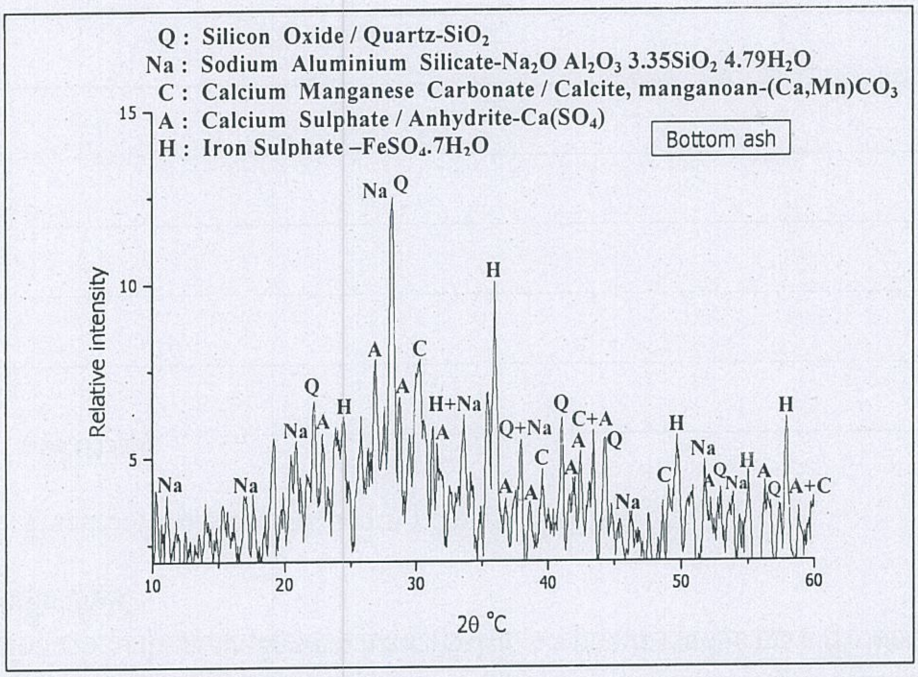
Ratio BA:FGDG:PC:SD	Property			
	Water absorption (%)	Density (g/cm^3)	pH	CEC (meq/100g)
10:80:10:0	50	1.96	7.72	2.0
30:60:10:0	46	2.11	7.82	2.2
10:60:30:0	40	2.31	6.68	2.8
40:40:20:0	41	2.14	7.80	4.3
20:40:40:0	41	2.46	7.09	5.6
60:30:10:0	40	2.33	8.07	4.0
10:30:60:0	36	2.53	6.55	7.3
40:20:40:0	37	2.24	6.73	6.4
80:10:10:0	31	2.24	8.61	4.8
60:10:30:0	31	2.32	7.80	6.1
30:10:60:0	28	2.77	6.85	8.0
10:10:80:0	28	2.84	5.78	9.4
26:9:52:13	38	1.54	6.03	8.6
24:8:48:20	46	1.69	6.19	8.7
22:7:45:26	50	1.21	6.43	8.9

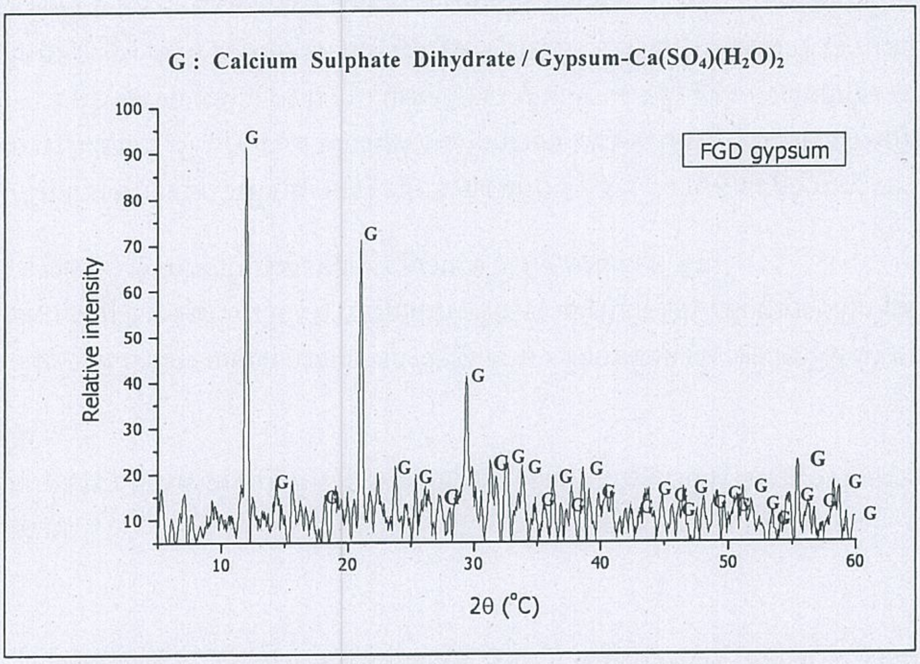
Table 3. Properties of bottom ash-FGD gypsum-paddy clay based mixtures with sawdust 26% compared with traditional planting material.

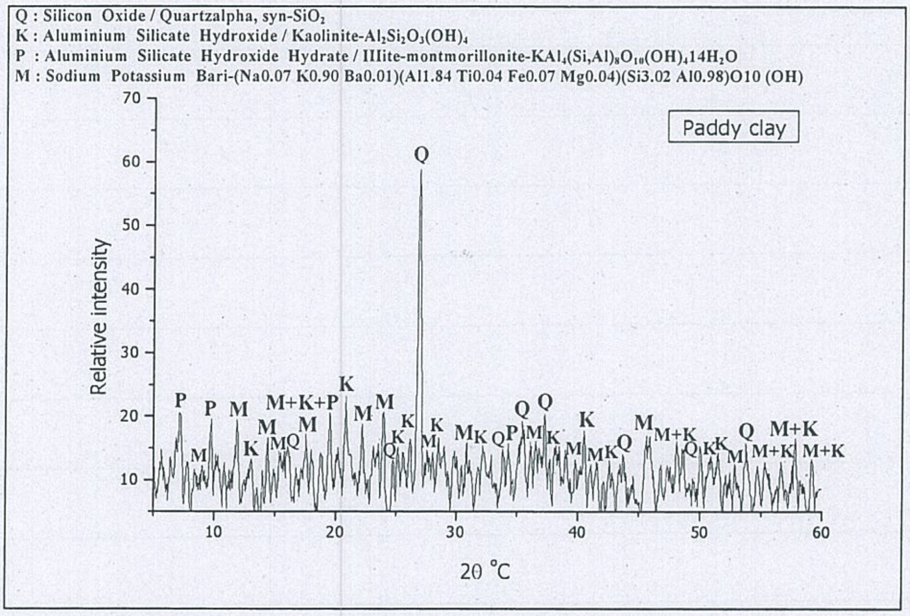
Property	BA:FGD gypsum:PC: SD; 22:7:45:26	Traditional planting material #
Water absorption (%)	50	45-65
Density (g.cm^{-3})	1.21	0.72-1.28
pH	6.43	5.5-6.5
CEC (meq/100g)	8.9	6-15

refer from reference [15]

However, addition of 26% by weight of sawdust was increased pores in planting materials after burning and improved. The results in Table 2, showed that the weight ratio of bottom ash – FGD gypsum – paddy clay at 30:10:60 and firing at 850 °C for 30 minutes with the increasing rate 3 °C/minute, from room temperature was the best condition. This planting material has initial nutrient compositions but some properties were not in agreement with the commercial ones. This was improved by adding 26% by weight sawdust. The improved planting material has the ability to absorb and retain large quantities of water for plant use between irrigations. It is slightly acidic with a pH of 6.43 and light weight (density = 1.21 g/cm^3). Traditional planting material should have a pH range of 5.5-6.5 with density in the range 0.72-1.28 g/cm^3 (Table 3) for plant growth and hydroponic use because it does not affect the carefully controlled nutrient and pH levels of the nutrient solution. The cation exchange capacities (CEC) value of the planting material produced is 8.9 meq/100g. It has a higher CEC value than hydroton (1.2 meq/100g), perlite (1.5 meq/100g) and kaolinite (3-15 meq/100g). The high CEC value correlates with a high nutrient holding capacity and thus retains nutrients for plant uptake between applications of fertilizer.


Q : Silicon Oxide / Quartz-SiO_2
Na : Sodium Aluminium Silicate-Na_2O Al_2O_3 $3.35SiO_2$ $4.79H_2O$
C : Calcium Manganese Carbonate / Calcite, manganoan-$(Ca,Mn)CO_3$
A : Calcium Sulphate / Anhydrite-$Ca(SO_4)$
H : Iron Sulphate –$FeSO_4.7H_2O$
Bottom ash
Relative intensity
2θ °C


G : Calcium Sulphate Dihydrate / Gypsum-$Ca(SO_4)(H_2O)_2$
FGD gypsum
Relative intensity
2θ (°C)



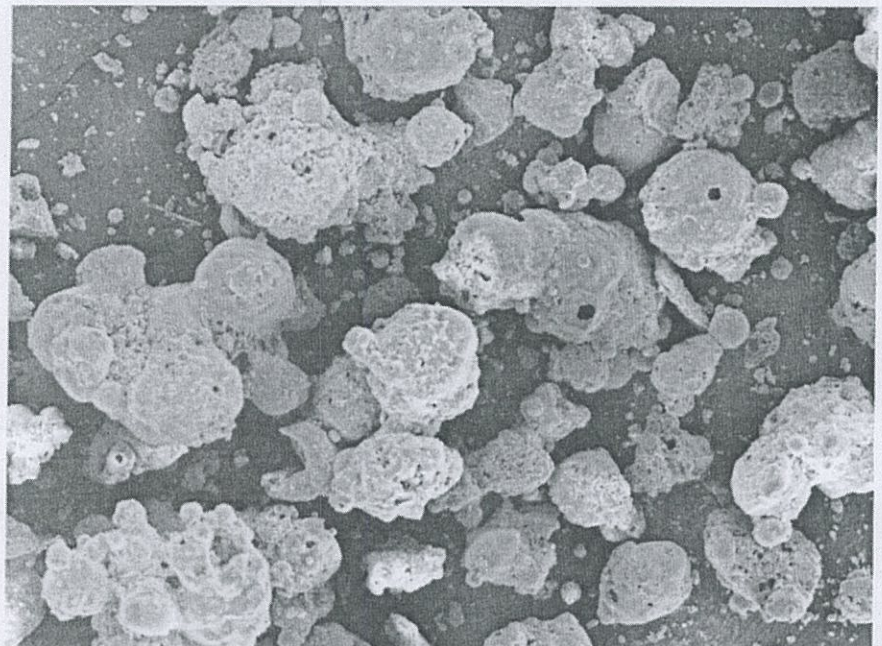


Figure 3. SEM photographs of the bottom ash

4. CONCLUSIONS

The advantage of this work is to use bottom ash and FGD gypsum residues from Mae Moh power plants with paddy clay and sawdust as raw materials for manufacturing (producing) of fired planting material. This study shows that mixed solid wastes (bottom ash, FGD gypsum, paddy clay and sawdust) at ratio 22:7:45:26 and fired at 850 °C for 30 minutes, with an increasing rate 3 °C/minute, results in the best planting material. It has nutrient components such as P, K, Ca, Mg, Fe, Mn and Ba which are plant essential nutrients. The amounts of P, K, Mg and Mn are comparable to amounts found in hydroton. This material did not slake when soaked 30 days under water. The new planting material has good water absorption, a slightly acidic pH value, and low density. The CEC value of this planting material was 8.9 meq/100g. It has a higher CEC value than that of hydroton, perlite and kaolinite.

5. ACKNOWLEDGEMENTS

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