PC14: การผลิตวัสดุปลูกที่มีเถ้าหนักและเอฟจีดียิปซัมจากโรงไฟฟ้าแม่เมาะ

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บทคัดย่อ

งานวิจัยนี้มีวัตถุประสงค์ที่จะใช้ประโยชน์ของเถ้าหนัก และเอฟจีดียิปซัม ซึ่งเป็นกากของเสียจากโรงงานไฟฟ้าแม่เมาะ จังหวัดลำปาง สำหรับผลิตเป็นวัสดุปลูกพืช เพื่อทดแทนวัสดุปลูกที่ได้จากธรรมชาติ ในการทดลอง เถ้าหนักและเอฟจีดียิปซัมถูกนำมาผสมกับดินท้องนาและขี้เลื่อย พบว่าวัสดุปลูกที่ได้ไม่ยุ่ยตัวหลังจากแช่ในน้ำไม่น้อยกว่า 30 วัน สามารถดูดซับน้ำได้ดี มีค่าพีเอชเป็นกรดเล็กน้อย (พีเอช 6.4) น้ำหนักเบา และมีค่าการแลกเปลี่ยนประจุบวกค่อนข้างสูง จากผลการวิเคราะห์ด้วยเอกซ์เรย์ฟลูออเรสเซนต์และเอกซ์เรย์ดิฟแฟรกชัน พบว่า วัสดุปลูกที่ได้มีสารอาหารหลักของพืชเช่น โพแทสเซียม ฟอสฟอรัส แคลเซียม แมกนีเซียม เหล็ก แมงกานีส และแบเรียม และพบว่ามีปริมาณไอออนของโลหะเช่นแคดเมียม(II) และนิกเกิล(II) ที่ปล่อยออกมาในปริมาณต่ำกว่า(แคดเมียม(II) 0.533 mg/mL และนิกเกิล(II) 0.533 mg/mLที่พีเอช 2)ระดับความเป็นพิษของไอออนเหล่านี้ในพืช

คำสำคัญ: เถ้าหนัก เอฟจีดียิปซัม วัสดุปลูก

Production of Planting Material Using Bottom Ash and FGD Gypsum from Mae Moh Power Plant

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Abstract

Bottom ash and flue gas desulfurization (FGD) gypsum, which are residues from Mae Moh power plant in Lampang province, can be used as instant planting materials. The aim of this research is to fabricate an instant implant material by mixing the bottom ash and FGD with paddy clay and sawdust to replace the use natural planting materials. It was found that the planting material obtained from this work did not slake after soaking at least 30 days in water. The planting material exhibited good water absorption, slightly acidic pH value (pH 6.4) and light weight with a rather high cation exchange capacity. The analysis by X-ray fluorescence and X-ray diffraction indicated that the planting material contained many elements which are essential for plant nutrients such as potassium, phosphorus, calcium, magnesium, iron, manganese and barium. It was also found that the amounts of heavy metal ions such as Cd^{2+} and Ni^{2+} released were lower than (Cd(II) 0.533 mg/mL and Ni(II) 0.533 mg/mLat pH 2) the toxicity level of these ions in plant.

Keywords: Bottom ash, FGD Gypsum, Planting Material

1. Introduction

At present, planting materials are important for the production of many plants grown in containers. Planting material is used as one kind of soil-less culture which covers all methods and systems of growing plants without soil, such as water culture, soil-less media culture, substrate culture and chemiculture. There is a wide range of waste materials used in the production of planting materials such as peat, bark, rice hulls, coconut fiber, sand, rockwood, perlite, vermiculite and calcined soils. This study focuses on bottom ash (BA) and flue gas desulfurization (FGD) gypsum wastes as novel planting materials for plants to provide economic benefits, as the use of these residues means low cost production of high value products based on solid mixtures.

The production of power through combustion of lignite at the Mae Moh power plant in Lampang produces a huge amount of waste. Virtually every economical use of coal is affected by the amount and variety of waste products. The types of wastes which are left over from burning of coal are fly ash (FA), bottom ash (BA), boiler slag and FGD gypsum. Wastes in coal can be the source of deleterious pollutants and corrosive elements, but also a source of useful by-products. Since 1960 many applications were identified in previous years using BA and FGD gypsum as a substitute for light fill material in construction[1], as engineering material[2], soil amendment[3], improvement of the physical properties of soil[4-6], adsorbents of heavy metals and organic substances[7-10] in previous years. However, its capability to absorb fertilizers[11] is not much exploited so far.

Based on their characterizations and detail studies, BA and FGD gypsum can be used as low cost substrates in the production of fired planting material (FPM). In this study, they were mixed with paddy soil (PS), to which different amounts of sawdust were added. Firing sawdust can be used to improve the pores in materials and to provide higher porosity and water absorption (WA).

2. Materials, chemicals and instruments

2.1 Materials and chemicals

1) Bottom ash, Mae Moh Power Plant, Lampang, Thailand
2) FGD gypsum, Mae Moh Power Plant, Lampang, Thailand
3) Paddy soil, Paradon company, Thailand
4) Sawdust, Sangwanitwattana company, Thailand
5) Cadmium nitrate ($Cd(NO_3)_2$), AAS standard, Ajax, Australia
6) Nickel (II) nitrate ($Ni(NO_3)_2$, AAS standard, Ajax, Australia

2.2 Instruments

1) Flame atomic absorption spectrophotometer, series AA-275, Varian Company, Australia
2) Flame photometer, model PFP7, Jenway Company, England
3) Hammer mill, model serie 5657, Haan of Retch Company, Germany
4) Oven, model UNE 400, Memmert Company, Germany
5) Particle size analyzer, Mastersizer, Melvern Instrument Ltd
6) pH meter, model pH Scan wp 3+, Eutech Instruments Pte Ltd, Singapore
7) Scanning electron microscope, JSM 6335F
8) X-ray diffractometer, BrukerD8Advance Diffractometer
9) X-ray fluorescence spectrometry, Phillips MagiX PRO PW 2400 Sequential

3. Methodology

Each material; BA, FGD gypsum, PS and SD, was dried sequentially at 110 ^{o}C for 12 hours, 40 ^{o}C for 1 hour, 110 ^{o}C for 12 hours and 40 ^{o}C for 12 hours, in order to reach constant weight. Then the materials were crushed and sieved to different sizes (BA 100 mesh, FGD gypsum 100 mesh, PS 80 mesh and SD 80 mesh) by hammer mill and sieving machine, respectively. The three raw materials (BA, FGD gypsum and PS) were mixed in different proportions to produce mixtures and combined with different percentages of SD (sieved at 80 mesh). From each mixture a wet powder was produced by adding 10% of distilled water. The wet powders were compressed into metallic moulds to form granules (diameter 0.8 mm and height 1 mm). These granules were fired in a half cubic meter furnace, using liquid petroleum gas (LPG) as a fuel. Initially, all samples were dried at 100 ^{o}C, then fired at various temperatures (600, 700, 800, 850, 900 and 1000 ^{o}C) with a heating rate of 3 ^{o}C/minute. The physical and chemical properties of the FPM, such as slake, water absorption, densiry, pH and cation exchange capacity (CEC) were measured. The chemical compositions of the best FPM produced were obtained by X-ray fluorescence (XRF) spectrometry and 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 and the morphology of the best FPM were obtained by X-ray diffraction (XRD) patterns from randomly oriented powder mounts using Cu Kα radiation and Scanning Electron Microscopy (SEM), respectively. Some heavy metals (cadmium and nickel) released from the FPM in buffer at various pH (6.5, 5.0 and 2.0) was measured by atomic absorption spectrophotometer.

4. Results and Discussion

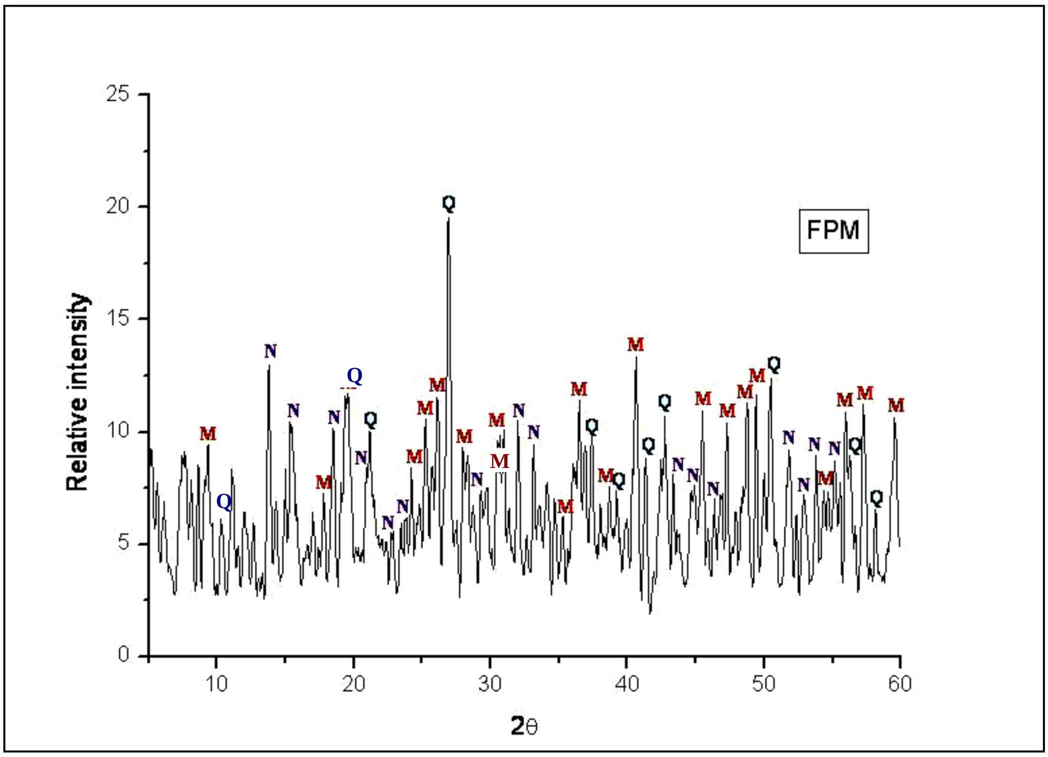
Every formulation of planting material fired to 850 ^{o}C did not slake when submerged in water for more than 30 days. High water absorption and low density depend on the percent by weight of FGD gypsum, but a high ratio of FGD gypsum results in a low CEC value. It was found that the weight ratio of bottom ash:FGD gypsum :paddy soil:saw dust at 22:7:45:26 fired at 850 ^{o}C for 30 minutes with a heating rate of 3 ^{o}C/minute provided the best conditions. This FPM has the ability to absorb and retain large quantities of water (50% water absorption) for plant use between irrigations due to its high porosity. It is slightly acidic with a pH of 6.4, has light weight (density = 1.2 g/cm^3) and rather high CEC value of 9 meq/100 g. The high CEC value correlates with a high nutrient holding capacity and thus retains nutrients for plant uptake between applications of fertilizer. It has a higher CEC value than the commercial planting material “hydroball” (1.2 meq/100g), and perlite (1.5 meq/100g). The ability of certain media to retain nutrients against leaching losses is related to its CEC. The CEC is the ability of the media to attract and hold various cations such as potassium, calcium, magnesium and iron ions for use by the plant’s roots. These positively charged ions are attracted to the negatively charged media particles and therefore aren’t leached as quickly from the media.

The chemical and mineralogical compositions of the best FPM were measured using XRF and XRD as shown in Table 1 and Figure 1, respectively. As shown in Table 1, the major chemical components of bottom ash are silica (SiO_2), alumina (Al_2O_3), calcium oxide (CaO) and ferric oxide (Fe_2O_3). These results agree with the XRD findings. The results present the major constituents of traditional planting material are Si, Al, Ca, Fe, K, Mg, P, Mn, Na and Ti. These are typical 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, and Mn are only minor nutrients for plants. The mineralogical compositions of the best FPM are summarized in Figure 1.

Table 1 Chemical compositions of the best FPM.

Compound	*Macro-elements (wt%)*
SiO_2	49.74
Al_2O_3	14.47
CaO^{**}	12.59
$Fe_2O_3^{*}$	5.84
K_2O^{**}	1.99
MgO^{**}	0.90
$P_2O_5^{**}$	0.07
MnO^{*}	0.08
Na_2O	0.32
TiO_2	0.54
LOI.	14.03
SiO_2	49.74

*LOI. = loss on iggition, ** = major nutrient of plant, * = minor nutrient of plant*



Q = quartz

d [Å]	2 Theta	Intensity
7.5750	11.673	75
4.2709	20.782	100
3.0556	26.203	52

N = natrolite

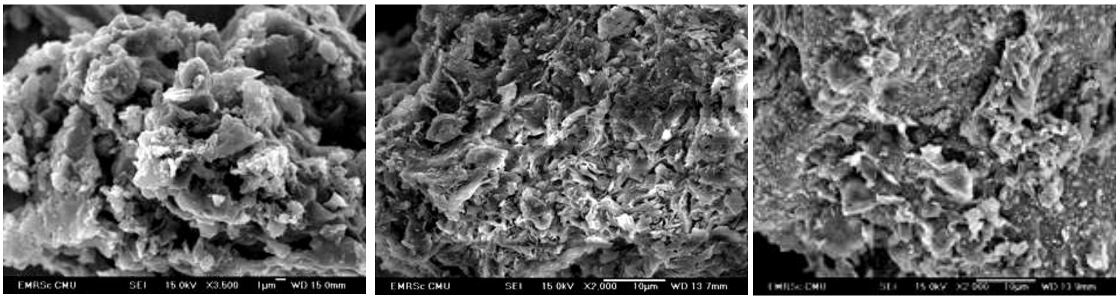
d [Å]	2 Theta	Intensity
6.3920	13.843	100
5.7856	15.302	79
2.8224	31.676	44

M = muscovite

d [Å]	2 Theta	Intensity
2.5528	35.125	100
4.4476	19.947	80
2.9381	30.399	68

Figure 1 X-ray diffraction of the best FPM: Q = quartz, N = natrolite and M = muscovite.

According to Figure 2, the scanning electron microscopy (SEM) images show that the best FPM consists of hollow spheres. At higher size ranges, porous sponge-like particles were detected. Therefore, it is suggested that the FPM could be used as nutrient adsorbent. Upon heating, the pore structure of planting material changes. When the FGD gypsum ($CaSO_4.2H_2O$) was heated at temperatures of 150, 200 and 400 ^oC, it changed from gypsum ($CaSO_4.2H_2O$) to hemihydrate ($CaSO_4.1/2H_2O$), to more spacious anhydrite III ($CaSO_4$ III), to more spacious anhydrite II ($CaSO_4$ II) and to anhydrite I ($CaSO_4$ I), respectively[12]. For paddy soil, the following changes were observed: water loss at 100 ^oC, combustion of organic matters at 200 ^oC, a change from α-quartz to β-quartz at 575 ^oC and decomposition of sodium carbonate at 600-850 ^oC[13]. According to the changes above, the generated gases inside the hot glowing body, such as carbon dioxide and/or carbon monoxide, caused the porous structure.



(a) (b) (c)

Figure 2 Scanning electron microscopy (SEM) images of the best FPM fired at (a) 850 ^oC (b) 900 ^oC and (c) 1000 ^oC.

Firing at higher temperatures at 900 ^oC and 1000 ^oC (Table 2) could not improve the properties of the planting materials. The firing FPMs at both 900 and 1000 ^oC had lower CEC and water absorption than those prepared at 850 ^oC because at higher temperature the humus was destroyed and the surface of the materials fused so the surface area decreased (Fig 2b, 2c).

Table 2 The properties of the best FPM fired at various temperature at a rate of 3 ^oC/minute.

Firing temperature (^oC)	Slake	%WA	Density (g/cm^3)	pH	CEC (meq/100 g)
800	*ns*	50	1.2	6.4	9
900	*ns*	50	1.2	6.5	8
1000	*ns*	49	1.3	6.3	7

WA = water absorption, CEC = cation exchange capacity, ns = not slake

The released of cadmium and nickel ions from FPM at various pH was studied using atomic absorption spectrometry. Table 3 shows that the FPM in neutral solution (pH 6.5) released a lower amount of Cd^{2+} and Ni^{2+} compared to FPM in acidic solutions (pH 5.0 and 2.0). This indicated that the pH is an important factor governing the release of these two heavy metals. Therefore, it might be concluded that the release of cadmium and nickel ions decreased with increasing the pH.

Table 3 Heavy metals release from FPM and HDB.

pH	Cd(II) (mg/L)	Ni(II) (mg/L)
6.5	< 0.002	< 0.005
5	0.013	< 0.005
2	0.533	0.167

Notice: Toxicity level in plant of cadmium 4-200 mg/L and nickel 8-200 mg/L.

5. Summary

It is found that a mixture of solid wastes (BA, FGD gypsum, PS and sawdust) at a ratio of 22:7:45:26 and fired at 850 ^{o}C for 30 minutes (at a rate of 3 ^{o}C/minute), gives the best planting material. It contains nutrient components such as P, K, Ca, Mg, Fe, Mn and Ba which are plant essential nutrients. This material did not slake when soaked 30 days under water. It provided good water absorption, a slightly acidic pH value, and low density. The CEC value of this planting material was 8.9 meq/100g. which is higher than that of the commercial "hydroball". Finally, the study of the release of cadmium and nickel ions from FPM and HDB at various pH values (pH 6.5, 5.0 and 2.0) indicated that the amounts of heavy metals (Cd^{2+} and Ni^{+}) released from FPM and HDB are lower than the toxicity level of Cd^{2+} and Ni^{+} in plants. Therefore, BA, FGD gypsum, PC and sawdust could be used as raw materials for production of planting materials. The best FPM prepared from this work has some properties that suitable for the plants grow.

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