การพัฒนากากตะกอนระบบบำบัดน้ำเสียจากโรงไฟฟ้าเป็นวัสดุปลูก

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บทคัดย่อ

การพัฒนากากตะกอนระบบบำบัดน้ำเสียจากโรงไฟฟ้าที่ใช้ถ่านหินเพื่อเป็นวัสดุปลูก ดำเนินการ 3 ขั้นตอน ประกอบด้วย (1) การปรับปรุงคุณสมบัติทางกายภาพด้วยวัสดุในท้องถิ่น ได้แก่ แกลบ ขุยมะพร้าว ขี้เลื่อย และกากชานอ้อย (2) การปรับปรุงคุณสมบัติทางเคมี ได้แก่ การผสมกับกากถั่วเหลืองและการเพาะถั่วเขียวเป็นพืชปุ๋ยสดในวัสดุปลูก รวมทั้ง (3) การทดสอบปลูกพืชในวัสดุปลูก พบว่า วัสดุปลูกที่เตรียมโดยใช้อัตราส่วนระหว่างกากตะกอนระบบบำบัดน้ำเสีย:ขี้เลื่อย:แกลบ เท่ากับ 5:1:1 จากนั้นปรับปรุงคุณสมบัติทางเคมีด้วยวิธีการปลูกพืชปุ๋ยสดเป็นวัสดุปลูกที่เหมาะสมที่สุด เมื่อเปรียบเทียบผลการปลูกพริกและมะเขือเทศในวัสดุปลูกดังกล่าวกับดินร่วนจากจำนวนใบและความสูงของพืช พบว่าพริกและมะเขือเทศสามารถเจริญเติบโตในวัสดุปลูกดังกล่าวได้ดีกว่าการปลูกในดินร่วนอย่างมีนัยสำคัญ ($P<0.05$)

คำสำคัญ: วัสดุปลูก กากตะกอนระบบบำบัดน้ำเสีย การใช้ประโยชน์ โรงไฟฟ้า

Development of Coal-fired Power Plant Sludge for Growing medium

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Abstract

Development of sludge which obtained from coal-fired power plant wastewater treatment to formulate growing medium was operated 3 steps. Firstly, physical properties improvement using local raw materials which were rice husk, coconut fiber, sawdust and bagasse. Secondly, chemical properties of sludge was improved by mixing with soybean meal and mung bean composting with sludge. The last procedure was plant testing. It was summarized that growing medium developed from mixing sludge: sawdust: rice husk in a ratio of 5:1:1 with decomposed mung bean was the most appropriated to use as growing medium. Likewise, bird chili and tomato cultivated in growing medium results were compared with loamy soil indicated from the quantity of leaf and stalk height. It was revealed the bird chili and tomato could be more vegetative in growing medium than planted in loamy soil significantly ($P<0.05$).

Keywords: growing medium, sludge, utilization, power plants

1. Introduction

Eco-industry is an integrated business management to the resource usage efficiency or enhances the opportunities for waste utilization serve a material substitution. Nowadays, the eco-industry policy has become approach in many industries including the coal-fired power plant. Many research studies were suggested the utilization of coal-fired power plant waste. Noteworthy reported that mostly waste from the coal-fired power plant was used as construction material but rarely of it were utilized for agriculture. Concerning to mentioned data it causing to this research study which was aimed to utilized the sludge for agriculture as formulate the growing medium from wastewater sludge of coal-fired power plant.

Implied by ideal soil composition which were consisted of 4 major components of the total soil volume: 50% is solid space, 45% is inorganic compound and 5% is organic matter. Optimum moisture and pore space for plant growth is divided roughly in half, 25% for air space and 25% for water retention (Mandal, 2013: 58-132). Furthermore, the sludge characterization which crumbled when dried but clumped when it got wet. It was brought about to the hypothesis that wastewater sludge played the role as the solid volume of growing medium so it required local and low-cost material to adjust the physical properties which were defined by abbreviation, M1, and M2. While M1 means material could adjust the water absorbed while M2 means material could be improving the bulk density value (total of bulk volume and external volume) suitably. Water absorption and bulk density are important physical properties for plant growth due to water essential for metabolic activities of the plant. For bulk density which was described as the weight of oven-dry soil per unit bulk volume, including air space (Bauer, 1974: 48-52). It was affecting porosity (Kakaire et al., 2015: 127-135) that important to the physical parameter, given its relationship to root growth and the fraction of water and air (Barros et al., 2016: 213-221).

Not only physical properties but also the chemical properties were considered because it was important affected to plant growth. Due to sludge properties that were analyzed by 2 sources as waste management center and Land Development Office (LDD). Waste management center analyzed the toxic substance by atomic absorption spectroscopy. The results were reported in table 1.

Table 1 Chemical properties of dry sludge from wastewater treatment of coal-fired power plant

Parameter	Method of analysis by total concentration[1]		Method of analysis by WET[2]	
	Result (mg/kg)	Standard (mg/kg)	Result (mg/kg)	Standard (mg/kg)
Cd	1.61	< 100	< 0.01	< 1.0
Cr (II)	< 0.5	< 2,500	< 0.1	< 5.0
Cr (III)	< 0.5	< 500	< 0.02	< 5.0
Cu	143	< 2,500	< 0.05	< 25
Pb	< 0.01	< 1,000	< 0.01	< 5.0
Hg	0.481	< 20	0.007	< 0.2
Ni	7.64	< 2,000	< 0.01	< 20
pH	6	-	-	-
Zn	79.07	< 5,000	0.21	< 250

[1] Total Threshold Limit Concentration (TTLC)

[2] Soluble Threshold Limit Concentration (STLC)

All parameter did not exceed the standard of the announcement of industry ministry: disposal of waste or unused materials 2005 (Department of industrial works, 2006). So it was not the toxic substance. The other one was LDD analyzed the major nutrient in wastewater sludge it was found 1.42% organic matter (O.M.), 0.07% nitrogen (N), phosphorus (P) by bray III method equaled 149.96% and potassium (K) extracted with NH_4OAc equaled 41.4 ppm. Compared with the data that reported as 1-6% N, 0.2-0.5% P, 1.5-4% K (Mills and Jones referred from Werner, 2010) and 3-6% O.M. (Cornell University, 2008) were sufficiency range of essential mineral in growing medium. It was indicated this study should improve O.M. and N. by any improvement methods. After that, the plant growth would be tested, this research selected to cultivate bird chili and tomato in growing medium because it has been observed that tomato plants absorb greater amounts of heavy metals (Trebolazabala et al., 2017: 161-169). For bird chili, it was suitable for the growing medium assessment and indicated N and K in growing medium because bird chili necessary to use nutrient especially N and K for the upward growth (Nitedpatpong et al., 2016: 2). Eventually, all of the research results represented the method to formulate the growing medium that anyone could implement easily.

2. Materials and Method

2.1 Raw materials preparation

Raw materials were consisted of activated sludge from the wastewater treatment of coal-fired power plant, rice husk, coconut fiber, sawdust, bagasse and soymeal as shown in figure 1. Dried the materials at ambient temperature and kept it out of the moisture.

Figure 1 Raw materials to formulate the growing medium

(a) wastewater sludge (b) rice husk (c) sawdust (d) bagasse (e) coconut fiber (f) soybean meal

2.2 Physical properties improvement

The physical properties of growing materials were determined using the following methodology

2.2.1 Water absorption

An aluminum canned that known precision volume and had the drainage hole seal at the bottom was filled with the growing medium. Poured water into the growing medium slowly until it was saturated by water. Afterward, removed hole seal to allow free water drained out of the growing medium 10 minutes. Weighted the growing medium and recorded as wet weight. Next, dried the growing media canned in the hot-air oven at 105°C for 24 hours. Recorded the weight of the growing media after took out from the oven as dry weight. Calculated the amount of water absorption by formula (1)

$$A = \frac{W - D}{D} \times 100 \qquad (1)$$

A is water absorption (%), W is wet weight (g), and D is dry weight (g)

2.2.2 Bulk density

Dried the aluminum can that contained with growing medium in a hot-air oven at 105 °C for 24 hours. Weighted and recorded the constant dry weight of the growing medium later. Bulk density could calculate by dry mass of growing medium divided by the unit volume of an aluminum can as formula (2)

$$BD = \frac{M}{V} \qquad (2)$$

BD is bulk density (g/kg), M is mass (g), and V is volume (cm^3)

Compared results then selected 2 appropriate materials, firstly type (M1) would be used to improve the water absorption and secondly type (M2) would be used to improve the density of growing medium. Subsequently, mixed the sludge (S) with 2 selected materials as varies ratio, Initialize the ratio of SL:M1:M2 equaled 2:1:1. The ratio of M1 and M2 were fixed at 1:1 but increased the amount of sludge until the water absorption of growing medium could not be measured because of sludge was excessive. Water absorption and bulk density were repeat tested to analyze the optimal ratio of SL:M1:M2

2.3 Chemical properties improvement

Improved the chemical properties by 2 methods as follows: (1) Mixed with soybean meal (SB) by different ratios as SL:M1:M2:SB equaled SL:M1:M2:0.5, SL:M1:M2:1, SL:M1:M2:1.5 and SL:M1:M2:2 (2) Cultivated with mung bean (*Vigna radiata* L.), legumes which provide to fix nitrogen over other plant species (Singh, 1997: 289-291). The cultivation was proceeded by soaked mung bean 500 g for 12 hours and planted on growing medium 5,000 g. or the ratio of mung bean: sludge equaled 1:10 w/w. 5 days later, shoveled thoroughly. Watering with Super LDD.1, Microbial activator solution which made by LDD. 500 ml/day continuous every day for 1 month. Analyzed the nutrients as follows; Ammonium-nitrogen (NH_4^+-N), Nitrate-nitrogen (NO_3^- -N), Available- phosphorus (P), Available-potassium (K) and organic matter (OM) using soil test kit of Kasetsart University Research and Development Institute and following the recommended standard testing procedures for all tested parameters.

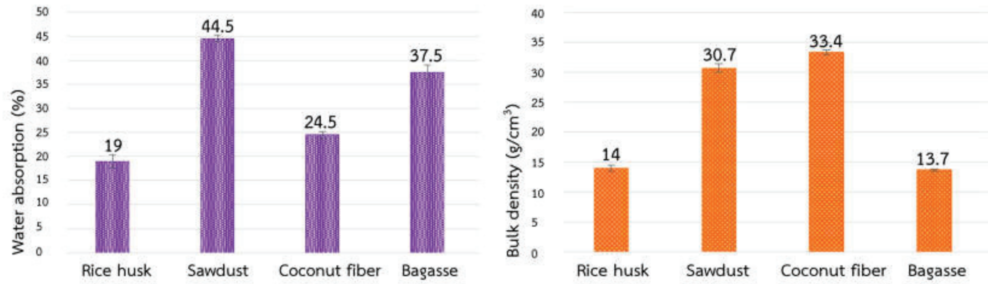
2.4 Planting test

Prepared growing medium using the results from 2.2.1 and 2.2.2. Later, assessed the feasibility of growing medium by grew up 2 plant species. Chili and tomato seeds were cultivated in plastic pots that filled with loamy soil or growing medium 75% by volume. Regular watering was done in each pot 300 ml/day for 1month. Later, estimated the plant growth by counted the number of the leaf also measured the stalk height that not included plant root by freeware as Image j Fiji.

3. Results and Discussion

3.1 Materials types to improve the physical properties of growing medium

Due to the wastewater sludge characteristic that was very low density when it was dried and agglomerated clumped when it was wet. It was necessary to improve those properties which related to the capable of plant growth. So this experimental step was taken to find out the properly 2 type of material to mix all together that could increase the porosity and water absorbability of growing medium. Each material was tested and reported the results as figure 2.



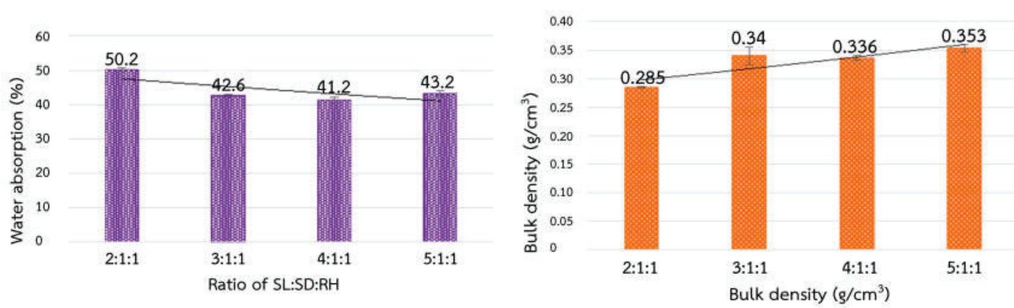
(a) (b)

Figure 2 Physical properties of raw materials

(a) water absorption of material (%) (b) bulk density of material (g/cm^3)

Referred from the sludge properties and the experimental results, it was found that water absorption of sawdust was maximum or equals 44.5±0.7%, thereby it was appropriated to absorb water or moisture for sludge. For the material which suitable to improve bulk density of growing medium, both sawdust and coconut fiber had highly bulk density so it was not preferred to use. For rice husk and bagasse fiber, the results were not significantly different (t-test; $p>0.05$). Therefore, this research considered the other factors as cost and material source, it was revealed the cost per unit of rice husk had lower than bagasse also supplied source of the rice husk was widely found while sugarcane residues from sugar industries that located in a specific area, mostly of sugar industrial has a batch-process depended on sugarcane harvesting season. In addition, all of the bagasse from sugar production could be used as a raw material in that biomass power plant. Therefore, the rice husk was more suitable to adjust the bulk density of growing medium.

Next procedure, the ratio of growth media that composed of sludge, sawdust, and rice husk was estimated. Assumed by ideal soil consisted of 5% organic matter, 45% inorganic matter, 25% water, including 25% porosity and air also the characteristic of sludge, sawdust, and rice husk, it was decided that sludge represented as the organic and inorganic matter which equaled 50% or half of all growing media. Sawdust and rice husk represented as material adjusted for the porosity which was related to water absorption and air voids respectively. For mentioned assumption, the ratio of sludge (SL): rice husk (RH): sawdust (SD) should be equaled to 50:25:25 or 2:1:1 (v/v). However, the research objectives that required to utilize a large amount of sludge so the ratio of SL: RH: SD varied to 3:1:1, 4:1:1, 5:1:1 were tested. Water absorption and bulk density results of all proportions were shown in figure 3.



(a) (b)

Figure 3 Physical properties of growing medium

(a) water absorption of material (%) (b) bulk density of material (g/cm^3)

As the results of water absorption and bulk density of SH:SD:RH were shown in figure 3. Water could infiltrate into particles well because that density was low. Adding the sludge by proportion until the ratio of SL: RH: SD equaled 6:1:1 was observed that water could not be permeated into the growing medium thoroughly, so the values of water absorption and bulk density were non-detected. As the tendency of water absorption was related to bulk density conversely. The range of water absorption equaled 41.2-50.2%, anyway commonly expressed as soil moisture changes quickly and easily (Seneviratne et al., 2010: 125-161). Therefore, its values were acceptable that not very different. Reasonably by research objective to use a large amount of sludge, the ratio of SL:RH:SD was equaled 5:1:1 was selected to formulate growing medium in next experimental step.

3.2 Materials types to improve the chemical properties of growing medium

Growing medium consisted of properly ratio were treated to develop chemical properties by 2 methods as described in 2.3. After the developing step had finished, nutrients of the growing medium were analyzed and reported in table 2. Almost every ratio of developed growing medium was found NH_4^+-N highly. Opposed from NO_3^--N results which were very low, especially, it had not found NO_3^--N in growing medium that composted with mung bean. It might be explained that caused from microorganisms of LDD.1 solution in composting process were altered NO_3^--N to N_2O or N_2 that called denitrification reactions (Thongsree, 2012: 12-14)

Table 2 Chemical properties of growing medium improved by mixed with soybean meal and composted with mung bean

Nutrient	Sludge mixed with soybean meal (SL:RH:SD:SB)				Sludge composted with mung bean
	5:1:1:0.5	5:1:1:1	5:1:1:1.5	5:1:1:2	
NH_4^+-N	medium	high	high	high	high
NO_3^--N	very low	very low	very low	very low	non-detected
P	high	high	high	high	high
K	medium	medium	medium	medium	very high
OM	medium	high	medium	medium	high

However, mainly available-N that plant could be uptake to use is NH_4^+-N that generated from ammonification reaction due to NH_4^+-N is cation so it could be interacted with soil as well. For phosphorus analysis, it was found all of the growing medium samples had high phosphorus. Likewise, potassium values were high but dominant level as very high was found in growing media which composted with mung bean. Lastly, organic matter was analyzed, it was shown the value of organic matter in growing medium were in range medium to high.

3.3 Plant test of growing medium

After the development of the physical and chemical properties had finished, it was found the suitable formula of growing medium should be composed of SL: SD: RH equaled 5:1:1 and composted with mung bean later. Growing medium has developed already was shown in figure 4.

Figure 4 Growing medium

Then planting test procedure was done in the growing medium and continually observed for 1 month, after that growth of chili and tomato was represented in figure 5. It was shown plant could alive in growing medium dominantly. The average quantity of leafs was counted from bird chili and tomato grown in growing medium were equaled 14±1.63 pieces and 32.17±3.85 pieces respectively. That result of leaf quantity was higher than bird chili planted in loamy soil that equaled 5.17±0.69 pieces and tomato planted in loamy soil equaled 5.67±2.13 pieces significantly (t-test; $p<0.05$; P(T<=t) one-tail 2.88E-05). For the height of all plants measured by Image j Fiji. It was revealed growing medium gave efficiency yield higher than loamy soil, considered by the average height of bird chili planted in growing medium equaled 22.11±5.59 cm. Similarly, tomato height planted in growing medium which equaled 22.09± 0.76 cm. The results were higher than bird chili and tomato were grown in loamy soil significantly (t-test; $P<0.05$; P(T<=t) one-tail 5.94E-9)

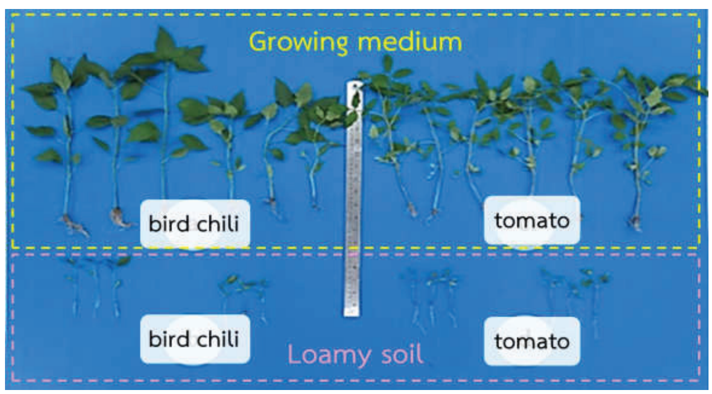


Figure 5 Growth comparison of planting test

4. Conclusion

Sludge from the wastewater treatment of coal-fired power plants could be developed as a growing medium by simplicity procedure as follow steps; mixed sludge with sawdust and rice husk. The mixing ratio of sludge: sawdust: rice husk equaled to 5:1:1. After that, cultivated the mung bean: sludge as 1:10 w/w for 5 days, shoveling and watering by LDD.1 solution 500 ml everyday continuous for 1 month to compost growing medium.

However, for more effective and reliable results, the research study should further have taken as follows; prudential design of experimental treatment should be concerned and examined, analyze the nutrients using the precise instrument test for the varied plant, weight yield of the plant should analyze, also the translocation and phytoaccumulation of the contaminant in plant and environment have to estimated and ensure for the cultivation.

5. Acknowledgement

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