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RESEARCH ON MIXING AND COMPOSTING SLUDGE FROM THE WASTEWATER TREATMENT SYSTEM AT THE COCA - COLA VIETNAM FACTORY, HANOI BRANCH TO CREATE PRODUCTS ORIENTED FOR PLANTING

Trinh Thi Thuy[1,*], Do Thi Kim Tuyen[2]

[1]Hanoi University of Natural Resources and Environment, Vietnam

[2]Tam Viet Environment and Construction Joint Stock Company, Vietnam

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Abstract

Sludge generated from the wastewater treatment systems of the beverage production industry represents a significant environmental concern. Reusing sludge is considered a sustainable approach. This study applied methods of blending sludge with other biomass materials, such as rice husk charcoal, followed by anaerobic composting. The results indicate that sludge from the wastewater treatment system of the Coca-Cola Vietnam factory, Hanoi branch, mixed with rice husk charcoal at a volumetric ratio of 80:20 and composted anaerobically for 30 days, produced a suitable substrate for tabletop ornamental plants. The study also suggests that this product has the potential to replace traditional growing media, thereby reducing treatment costs while simultaneously delivering both economic and environmental benefits.

Keywords: Sludge; Wastewater treatment; Ornamental plants.

[*]**Corresponding author, Email:** ttthuy.mt@hunre.edu.vn

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1. Introduction

In the wastewater treatment industry, sludge is the residue produced by biological and chemical wastewater treatment processes. Sludge from wastewater treatment processes can contain many organic substances, heavy metals, and other pollutants, which, if not properly managed, will negatively impact the water, soil, and air environment [1]. Many studies have confirmed that traditional methods, such as landfilling or incineration, often treat sludge. However, these methods are costly and pose a risk of environmental pollution [2]. Finding solutions to reuse sludge more effectively, such as producing fertilizers or environmentally friendly products, is receiving attention. Composting is an effective method to treat and stabilize sludge, transforming it into safe and nutritious products [3]. In Vietnam, some studies have been conducted on composting from industrial sludge, but mainly on sludge from seafood and beer processing [4, 5].

The beverage industry is growing strongly in Vietnam, with Coca-Cola being one of the leading brands. However, the beverage production process generates a large amount of wastewater and leads to sludge from the wastewater treatment system. The large volume of sludge generated at the factory is causing significant challenges for businesses and industrial waste management. If inadequately treated, sludge can result in adverse impacts on water, soil, and air environments. Currently, the predominant sludge treatment methods include landfilling and incineration. However, landfilling poses the risk of long-term environmental pollution, while incineration is associated with high operational costs. At the Coca-Cola Vietnam factory, Hanoi branch, although a modern wastewater treatment system has been implemented to ensure that the treated effluent meets environmental standards, a significant amount of sludge is still generated from the wastewater treatment process. Currently, the plant adopts landfilling as the primary method for sludge disposal. However, this approach is associated with high treatment costs and poses potential environmental risks [6]. Therefore, exploring options for reusing sludge to minimize costs and mitigate environmental impacts is crucial.

Nowadays, the trend of using bonsai trees for offices and homes is becoming more and more popular in big cities like Hanoi. Therefore, the demand for specialized soil, substrate, and fertilizer products for bonsai trees is increasing. However, research on developing these products by mixing sludge from wastewater treatment systems and other materials for use in ornamental plants still needs to be completed.

Rice husk charcoal, a product of rice husk combustion, is widely used in agriculture due to its superior properties [7]. Physically, rice husk charcoal has a porous structure with a large surface area, which helps improve the water retention and air permeability of the growing medium, which is especially important for bonsai grown in small pots [8]. Chemically, rice husk charcoal has a neutral to slightly alkaline pH, which helps balance the pH of acidic sludge [9] while adding trace elements such as silicon, potassium, and calcium, creating a balanced nutritional medium [10]. In addition, rice husk charcoal has natural antibacterial properties, limiting pathogens and creating a favorable environment for beneficial microorganisms, improving plant health.

Based on the above facts, this study aims to mix and compost sludge from the wastewater treatment system of the Coca-Cola Vietnam factory, Hanoi branch with rice husk charcoal to produce a product suitable for growing ornamental plants. The research holds not only scientific significance but also practical value, contributing to reducing waste treatment costs and creating an environmentally friendly, useful product.

2. Materials and methods

2.1. Materials

The sludge used in this study was collected from the wastewater treatment system of the Coca-Cola Vietnam factory, Hanoi branch. The sludge sample utilized for the research was obtained after the treatment process and dewatered into sludge cakes. Rice husk charcoal was procured from a water filtration materials supplier and was produced through the pyrolysis of rice husks under anaerobic conditions.

Three popular ornamental plants were selected for the study: *Philodendron Selloum* (Thanh Xuan pothos), *Philodendron emperor* (De Vuong pothos), and *Monstera deliciosa* (Monstera pothos). The selection of these three plants was based on their classification as low-maintenance species with strong growth adaptability under low-light conditions, making them well-suited for indoor or office spaces. This characteristic ensures that the results of the substrate trials can be broadly applicable to other indoor ornamental plants and office landscaping. Additionally, these plants have moderate nutrient requirements and can readily adapt to various substrate types. This makes them ideal for assessing the effectiveness of the new substrate composed of sludge blended with rice husk charcoal without the need for significant additional nutrient supplementation under normal conditions.

2.2. Research methods

2.2.1. Methods of analyzing sludge composition

The sludge composition is determined to guide its use as a growing medium. The methods of analyzing sludge composition are shown in Table 1.

Table 1. Indicators and analysis methods

No	Parameter	Method	STT	Parameter	Method
1	Moisture	TCVN 6648:2000	4	Total carbon	ISO 16948:2015
2	Flexible phosphorus	TCVN 10678:2015	5	Total nitrogen	ISO 16948:2015
3	Potassium	TCVN 8660 : 2011	6	Total sulfur	ISO 16948:2015

2.2.2. Experimental design method

a. Research on the different mixing ratios of sludge with rice husk charcoal and incubating time

Mix sludge and rice husk charcoal in volume ratios of 70:30, 75:25, 80:20, 85:15, and the total volume of the mixture is 0.2 m^3. The selected ratio range of 70:30 to 85:15 was chosen to balance the amount of sludge and rice husk charcoal, ensuring sufficient nutrient supply from the sludge while maintaining the porous structure provided by the rice husk charcoal. Additionally, this ratio range allows for effective control of salt levels and pH in the substrate, creating a healthy growth environment for plants.

Put the mixture into a styrofoam box with a lid and incubate the mixtures in order of 45 days, 30 days, and 15 days. One box of un incubated mixture was prepared on the final day of the incubation process. The boxes were finished incubating on the same day, then proceeded to plant trees. Do not disturb the mixture during the incubation process.

The mixtures after mixing and incubation were denoted as follows:

Table 2. Symbols of mixed mixtures between sludge and rice husk charcoal

Mixing ratio	Incubation time	ID of mixture	Mixing ratio	Incubation time	ID of mixture
70:30	No incubation	U1.0	80:20	No incubation	U3.0
	15 days	U1.1		15 days	U3.1
	30 days	U1.2		30 days	U3.2
	45 days	U1.3		45 days	U3.3
75:25	No incubation	U2.0	85:15	No incubation	U4.0
	15 days	U2.1		15 days	U4.1
	30 days	U2.2		30 days	U4.2
	45 days	U2.3		45 days	U4.3

- After incubation, the mixtures were analyzed for some basic parameters according to the methods in section 2.2.1.

b. Planting bonsai using the mixtures after incubating

For each experimental mixture, three types of plants are planted, including *Philodendron Selloum, Philodendron emperor,* and *Monstera deliciosa*. The mixtures, after incubation, were put into black nursery pots made from recycled PE plastic of 17 × 2.5 cm. The plants were seedlings that were purchased at the nursery. All plants were measured by height and the number of leaves. All ornamental plants were planted on the same day with the same care conditions (watering once a day, same amount of water). Each experimental model was repeated three times.

Control experiment: The *Philodendron Selloum*, *Philodendron emperor*, and *Monstera deliciosa* were grown on soil taken from a garden in Hong Van commune, Thuong Tin district, Hanoi city. Control experiments were denoted as MD.

Monitor the growth and development of the plant through the following parameters: Plant height, and number of leaves, with a measurement frequency of 40 days/1 data during the period of 4 months (from March 10, 2024 to July 10, 2024). The results were the average of 3 replicates for each experiment.

3. Results and discussion

3.1. Results of determination of the sludge composition

The results of the composition analysis of the sludge are shown in Table 3.

Table 3. Composition of sludge from the wastewater treatment system of Coca-Cola Vietnam factory, Hanoi branch

No	Parameters	ID	Unit	Sludge
1	Humidity	W	%	80, 54
2	Flexible phosphorus	P_2O_5	%	3, 63
3	Potassium	K	mg/100 g	0.675
4	Total Carbon	C	%	14.85
5	Total Nitrogen	N	%	1,236
6	Total sulfur	S	%	0.002

According to the data in Table 3, the sludge from the wastewater treatment system of the Coca-Cola Vietnam factory, Hanoi branch is a rich source of nutrients, especially in flexible phosphorus (3.63 % P_2O_5), total nitrogen (2.536 %) and total carbon (14.85 %). These values are similar to many other types of wastewater sludge [11] .

3.2. Results of sludge analysis after mixing and incubating with rice husk charcoal

The results of analysis of some components of the sludge after mixing and incubating with rice husk charcoal are shown in Table 4.

Table 4. Composition of the mixture of sludge and rice husk charcoal before and after incubating

ID of Mixture	Ingredient				ID of Mixture	Ingredient			
	P_2O_5 (%)	N (%)	C (%)	K (%)		P_2O_5 (%)	N (%)	C (%)	K (%)
U1.0	2.681	2.118	18.403	0.554	U3.0	3.271	2.050	26.897	0.418
U1.1	2.885	2.157	16.185	0.691	U3.1	2.151	2.134	15.829	0.877
U1.2	3.012	2.084	20.106	0.703	U3.2	3.173	2.208	20.135	0.871
U1.3	2.651	2.119	16.457	0.652	U3.3	3.338	2.177	18.185	0.782
U2.0	2.696	2.043	21.478	0.449	U4.0	3.210	2.026	22.980	0.597
U2.1	2.922	2.023	15.559	0.554	U4.1	3.143	1.737	19.546	0.601
U2.2	3.235	2.187	15.919	0.533	U4.2	2.971	1.975	17.498	0.664
U2.3	2.681	2.118	18.403	0.550	U4.3	2.892	1.932	15.961	0.456

According to the data in Table 4, after mixing the sludge with rice husk charcoal at different ratios and the days of incubating, the nutritional composition of the mixtures changed. The content of flexible phosphorus ranged from 2.151 to 3.338 %, which decreased compared to the original sludge but remained high. The total nitrogen content in the mixtures ranged from 1.737 to 2.208 %, which remained relatively stable and high. These mixtures were all rich in nitrogen. The organic carbon content in the mixtures ranged from 15.559 to 26.897 %, higher than that of the original sludge. This increase could be due to the contribution of rice husk charcoal, a carbon-rich material. The high C content helps improve soil structure and increase water retention, which is suitable for the nutritional needs of plants. The C/N ratio is about 10:1, suitable for microbial decomposition. Thus, regarding nutritional composition P, C, and N, the above mixtures are suitable for growing plants in general and growing bonsai in particular.

However, the total potassium content in the mixtures is quite low, ranging from only 0.418 to 0.877 mg/100 g. Therefore, when using these mixtures as growing media, it may be necessary to supplement the K source to ensure nutritional balance for the plants.

In terms of mix ratio, mixes with higher sludge ratios of 80:20 and 85:15, respectively, tend to have higher nutrient content. These results reflect the fact that the nutrient content of P, C, and N of sludge is often much higher than that of rice husk charcoal. Composting time also affects decomposition and nutrient conversion. Composting mixtures of 30 - 45 is generally more nutritionally stable.

When compared to organic compost derived from brewery and seafood processing sludge (37.12 - 54.74 % C, 1.81 - 2.39 % N, and 3.31 - 4.99 % P_2O_5) [4], the mixture of sludge from the wastewater treatment system of the Coca-Cola production plant and rice husk charcoal has significantly lower carbon and phosphorus content but exhibits a comparable total nitrogen percentage. Both mixtures have similarly low potassium levels, with K_2O only reaching 0.18 - 0.20 %, highlighting the need for potassium supplementation from other sources to balance the nutrients.

Compared to organic compost from shrimp pond sludge (19.91 - 23.75 % C, 1.59 - 3.95 % N, and 0.28 - 0.68 % P_2O_5) [12], the sludge-rice husk mixture demonstrates lower carbon content but comparable total nitrogen levels and higher available phosphorus content. Notably, the C/N ratio of the Coca-Cola wastewater sludge and rice husk mixture, approximately 10:1, is lower than that of shrimp pond sludge, which is approximately 23:1. This lower C/N ratio facilitates faster and more efficient organic decomposition. However, shrimp pond sludge, with its higher carbon content, is better suited for improving soils deficient in organic matter.

3.3. Results of growing test using waste sludge products after mixing and incubating

3.3.1. Results of survey on growth of tree based on the height

The height of the tree was measured in four batches (Batch 1: The first day of planting, Batch 2: After 40 days of planting, Batch 3: After 80 days of planting, Batch 4: After 120 days of planting). The data obtained are summarized in Table 5.

Table 5. Data on the height of ornamental plants

ID of mixture	Philodendron Selloum			Philodendron emperor			Monstera deliciosa		
	After 40 days	After 80 days	After 120 days	After 40 days	After 80 days	After 120 days	After 40 days	After 80 days	After 120 days
	(cm)			*(cm)*			*(cm)*		
MD	1.7	2.5	3.4	1.6	3.1	3.9	1.7	3.7	4.8
U1.0	1.8	2.8	3.8	1.9	3.0	4.1	1.8	4.7	5.8
U1.1	3.7	6.2	8.7	1.8	3.1	4.3	1.3	4.3	6.0
U1.2	3.9	6.4	8.9	1.3	2.7	4.0	1.8	4.6	5.5
U1.3	3.8	6.3	8.8	1.4	3.0	4.5	1.5	4.8	6.5
U2.0	1.7	3.0	4.2	1.9	3.3	4.7	1.8	4.0	4.3
U2.1	3.6	5.8	7.9	1.1	2.4	3.7	2.0	5.9	7.8
U2.2	2.8	4.8	6.8	1.2	2.5	3.8	1.3	3.5	4.3
U2.3	3.7	5.2	6.7	1.9	3.8	5.7	2.5	5.4	5.8
U3.0	4.6	6.5	8.4	2.7	3.6	4.4	2.7	5.2	4.9
U3.1	2.8	5.0	7.2	2.2	3.5	4.8	1.6	4.6	6.0
U3.2	3.7	6.8	9.8	2.5	4.5	6.4	3.4	7.9	8.9
U3.3	3.4	7.0	9.2	2.3	5.4	7.2	2.0	4.8	8.1
U4.0	2.9	4.7	6.4	1.9	2.7	3.4	2.8	6.4	7.2
U4.1	2.7	5.1	7.4	3.5	4.8	6.0	2.5	6.1	7.1
U4.2	1.9	3.9	5.8	1.9	3.0	4.1	3.0	5.2	4.4
U4.3	3.6	5.9	8.1	1.8	3.1	4.3	2.2	4.7	4.9

According to the data in Table 5, most of the mixtures gave better results than the control experiment (MD) in all measurement batches. The results for the growing medium were labeled U3.2, and U3.3 (ratio 80:20:00, incubation for 30 and 45 days) gave the highest efficiency for all three types of pothos plants. The ratio of 80:20:00 provides a good balance between sewage sludge (the main source of nutrients) and rice husk charcoal (improves aeration). The mixture with this ratio optimizes the growing media's water retention and air permeability. The incubation time of 30 and 45 days allows the microbial decomposition process to take place fully, helping to stabilize the nutritional composition of the mixture. The combination of wastewater sludge from the water treatment system and rice husk charcoal can create a substrate with good porosity, water retention and aeration capacity, and adequate nutrition, which are important substrate characteristics for growing plants. Although there were slight differences between species, all three types of pothos grew well on substrates labeled U3.2 and U3.3. The mixtures with 85 % wastewater sludge did not give the best results, although they were still better than the plants that were grown on garden soil (MD experiments). This may be due to the high proportion of wastewater sludge reducing the aeration of the substrate, affecting the development of the roots.

3.3.2. Results of survey on growth of tree based on the number of leaves

The number of leaves on the tree was counted in four batches at the same time as the height measurement (Table 6).

Table 6. Data on changes in the number of leaves

ID mixture	Philodendron Selloum			Philodendron emperor			Monstera deliciosa		
	After 40 days	After 80 days	After 120 days	After 40 days	After 80 days	After 120 days	After 40 days	After 80 days	After 120 days
	Number of leaves			Number of leaves			Number of leaves		
MD	2.0	3.0	4.0	2.0	3.0	4.0	1.0	2.0	3.0
U1.0	2.0	3.0	5.4	2.6	4.6	6.3	1.0	2.0	4.7
U1.1	1.3	2.3	4.3	2.0	4.0	6.0	2.0	3.0	5.0
U1.2	2.0	3.0	5.0	2.4	4.4	6.7	2.0	3.0	5.0
U1.3	2.4	3.4	6.4	2.0	4.0	6.0	1.0	2.0	4.0
U2.0	3.0	4.0	7.4	3.0	5.0	8.0	1.6	2.6	4.0
U2.1	3.0	5.0	7.0	2.4	4.4	8.0	2.0	3.0	4.0
U2.2	2.0	4.0	6.0	3.0	5.0	7.0	1.0	2.0	4.0
U2.3	2.0	4.0	7.0	2.0	4.0	6.0	1.0	2.0	4.0
U3.0	2.4	4.4	5.7	3.0	5.0	7.4	2.4	3.4	5.0
U3.1	2.0	4.0	7.0	3.0	5.0	8.0	2.0	3.0	4.0
U3.2	3.4	5.4	8.0	3.0	5.0	8.0	2.0	3.0	6.4
U3.3	3.6	4.3	6.3	2.3	4.3	7.3	2.0	3.0	6.0
U4.0	2.4	3.4	6.4	2.0	4.0	5.0	1.0	2.0	5.0
U4.1	3.0	4.0	8.0	1.3	2.3	5.3	2.0	3.0	5.0
U4.2	2.0	3.0	6.4	3.0	4.0	6.0	2.0	3.0	5.0
U4.3	2.0	3.0	7.0	2.3	3.3	5.3	2.0	3.0	5.0

The data in Table 6 indicate the increased number of leaves of three types of pothos plants after 40, 80, and 120 days of planting. Similar to height growth, most ornamental plants grown in the mixtures showed better results than those grown in garden soil (MD) at all measurement batches. After 120 days, the U3.2 mixture continued to show outstanding effectiveness with an increased number of leaves for three types of pothos *(Philodendron Selloum, Philodendron emperor,* and *Monstera deliciosa*) with an average of 8, 8, and 6.4 leaves respectively. Compared to the MD (4, 4, and 3 leaves), the plants in U3.2 developed from 2 to 2.13 times more leaves. The data collected from experiments reinforces the conclusion that the 80 % sludge ratio and 30-day incubation period create the optimal environment for the overall growth of pothos. Mixtures with sludge ratios from 70 - 80 % also have a positive effect on the leaf growth of the pothos plant.

Thus, it can be seen that the U3.2 mixture (sludge: Rice husk charcoal ratio 80:20, incubation for 30 days) gave the significant best results for all three types of pothos plants in terms of both height and number of leaves. The results reveal that the optimal balance between nutrients from the sludge and soil structure from the rice husk charcoal, along with a sufficiently long composting time to stabilize the organic matter, can support good conditions for plant growth. Mixtures in which the sludge accounted for about 70 - 80 % and an incubation time of 15 - 45 days also gave better results than the MD. However, a sludge ratio that was too high (85 %) did not give the best results that confirm the importance of balancing nutrients and soil structure in the growing medium.

4. Conclusion

The study has mixed sludge from the wastewater treatment system of the Coca-Cola Vietnam factory in Hanoi and rice husk charcoal with different mixing ratios, then incubated, and evaluated the effectiveness of using these mixtures to grow three types of ornamental plants: *Philodendron Selloum, Philodendron emperor,* and *Monstera deliciosa*. The results showed that most of the mixtures significantly improved plant growth compared to normal soil. The U3.2 mixture (waste sludge: Rice husk charcoal ratio 80:20 by volume, incubated for 30 days) was determined to be the most effective. Mixtures with a sludge ratio of 70 - 80 % and an incubation time of 15 - 45 days gave better results than mixtures with a sludge ratio of 85 %. This study shows the potential of reusing sludge from wastewater treatment systems as a growing medium. However, the study has not yet delved into the long-term impacts of these mixtures on plant health and the environment, particularly the potential accumulation of heavy metals and other toxic substances from sludge in soil and plants. Additionally, the scope of the research primarily focuses on ornamental plants and has not been extended to agricultural crops or various soil conditions, which limits the practical applicability of the findings on a larger scale.

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REFERENCES

[1]. Ahmad, T., Ahmad, K., Alam, M., (2016). *Characterization of water treatment plant's sludge and its safe disposal options: A review.* Procedia Environmental Sciences, 35, 950 - 955.

[2]. Marsland, T.,Whiteley, B., (2015). *Hazards from landspreading wastes, rapid Evidence Assessment: Effluent treatment sludge from the soft drinks industry*. Environment Agency.

[3]. Bernal, M.P. et al., (2009). *Composting of animal manures and chemical criteria for compost maturity assessment. A review*. Bioresource Technology, 100(22), 5444 - 5453.

[4]. Nguyen Thi Phuong, Nguyen My Hoa, Do Thi Xuan (2018). *Production and assessment efficiency of microbial-organic fertilizers from beer and seafood factories' sludge on vegetable yield.* Journal of Science, Can Tho University, 54, 81 - 89 (in Vietnamese).

[5]. Vo Phu Duc (2013). *Development of a production process for bio-organic fertilizer from sludge generated during the processing of pangasius fish*. Science and Technology Project of Dong Thap province (in Vietnamese).

[6]. Coca-Cola Vietnam (2022). *Sustainability Development Report*.

[7]. Agegnehu, G., Bass, A. M., Nelson, P. N., Bird, M. I., (2016). *Benefits of biochar, compost and biochar-compost for soil quality, maize yield and greenhouse gas emissions in tropical agricultural soil*. Science of the Total Environment, 543, 295 - 306.

[8]. Gu, Y., Xu, X., Wang, Y., Zhang, X., Ren, Y., (2013). *Growth responses of rice (Oryza sativa L.) to rice husk biochar amendment under rainfall stress condition*. Journal of Soils and Sediments, 13(8), 1421 - 1428.

[9]. Haefele, S. M., Konboon, Y., Wongboon, W., Amarante, S., Maarifat, A. A., Pfeiffer, E. M., Knoblauch, C., (2011). *Effects and fate of biochar from rice residues in rice-based systems*. Field Crops Research, 121(3), 430 - 440.

[10]. Pode, R., (2016). *Potential applications of rice husk ash waste from rice husk biomass power plant*. Renewable and Sustainable Energy Reviews, 53, 1468 - 1485.

[11]. Nguyen Thi Phuong, Nguyen My Hoa, Do Thi Xuan, Vo Thi Thu Tran, Lam Ngoc Tuyet (2016). *Characteristics of sludges from wastewater treatment plants of beer and seafood processing factories*. Journal of Science, Can Tho University, 45, 74 - 81 (in Vietnamese).

[12]. Do Thi Cam Van, Vu Dac Duy, Nguyen Thi Sen, Tran Nam Anh (2019). *Study on composition, characteristics of waste sludge from Nghe An shrimp raising-pond and evaluation of sludge quality for compost production*. Journal of Science & Technology, Hanoi University of Industry, 53, 90 - 95 (in Vietnamese).