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RESEARCHING THE SIMPLE SOLUTION OF COMPOSTING FOR THE MINIMIZATION OF FECAL COLIFORM IN SLUDGE DREDGED FROM HOAN KIEM LAKE IN HANOI - VIETNAM

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ABSTRACT

In Vietnam's urban areas, lakes play a very important role in climate regulation as well as contributing to flood protection. In the capital city of Hanoi, there are currently 142 lakes. These lakes are dredged annually and the sludge should be treated. Two types of matter present in the sludge require treatment: coliform and fecal coliform. The aim of this research is to utilise the simple solution of composting for treating the sludge which is dredged from Hoan Kiem Lake, Hanoi. Results from analyzing the sludge showed its contents: carbon 72.3 mg/g DM, nitrogen 7.9 mg/g DM and phosphorus 2 mg/g DM. Therefore, we focused our research on adding high carbon content materials (such as straw, husk and peat coal) urea and phosphorus. The research also involves the addititon of microorganism mixture Biomix, which includes Bacillus subtilis and Streptomyces in order to boost the composting process as well as to support the biological endeavor to reduce the coliform. The results show that the mixture containing 96% sludge, 3% rice straw and 1% compost mixed with the Biomix generated the best results. The time period of composting had effects on the density of fecal coliform.

Keywords: composting, fecal coliform, sludge, urban lake.

TÓM TẮT

Nghiên cứu phương pháp đơn giản ủ sinh học hiếu khí nhằm giảm thiểu fecal coliform trong bùn thải nạo vét từ Hồ Hoàn Kiếm - Hà Nội

Tại các đô thị ở Việt Nam, các hồ nội đô đóng vai trò rất quan trọng trong điều hòa khí hậu và góp phần hạn chế lũ lụt. Thủ đô Hà Nội có 142 hồ, hằng năm được nạo vét bùn. Bùn thải cần xử lí các thành phần coliform và fecal coliform. Mục đích của nghiên cứu nhằm phát triển phương pháp đơn giản ủ sinh học hiếu khí để xử lí bùn thải được nạo vét từ Hồ Hoàn Kiếm - Hà Nội. Kết quả phân tích cho thấy bùn thải có tỉ lệ Carbon 72,3 mg/g (chất khô), tỉ lệ Nitơ 7,9 mg/g (chất khô) và Phốt pho 2 mg/g DM (chất khô). Bùn thải được phối trộn với các nguyên liệu giàu carbon như rơm rạ, vỏ trấu, than bùn có bổ sung thêm urê và lân. Ngoài ra, nghiên cứu còn sử dụng chế phẩm vi sinh Biomix gồm các chủng Bacillus subtilis và Streptomyces nhằm đẩy nhanh quá trình mùn hóa và hỗ trợ khử coliform. Kết quả nghiên cứu cho thấy công thức với tỉ lệ phối trộn: 96% bùn, 3% rơm rạ, 1% compost phối trộn với chế phẩm Biomix cho ra kết quả tốt nhất sau 40 ngày ủ. Thời gian ủ ảnh hưởng lên mật độ fecal coliform.

Từ khóa: ủ hiếu khí, fecal coliform, bùn thải, hồ nội đô.

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1. Introduction

Rivers, lakes and ponds are natural regulatory systems for each country. They play important roles in the regulation of rainwater, flood reduction, habitats of aquatic flora and fauna, of which, lakes are a matter of concern in Hanoi city in recent years. According to latest statistics, the city of Hanoi has 142 lakes of which the inner Hanoi city (in 9 counties) has 110 lakes and 32 lakes in Ha Tay - Ha Noi area. Lakes are mainly climate regulating basins, a place of entertainment- sports for residents and also used in aquaculture.

Of the lakes in Hanoi, Hoan Kiem Lake is the most important, with respect to history, landscape and spirit thanks to the presence of a giant precious turtle. Hoan Kiem Lake was formed by a tributary of the Red River, covering an area of 18 ha and is now completely isolated. Currently, wastes, sludge and sediments are deposited in the lake by the rain. The lake has become a backwater as the water level decreases on a daily basis.

This research project is a component within the project of international cooperation tasks in science and technology associated with the Vietnam-Germany protocol "Research and application of German technology to stabilize and restore the environment of a number of lakes in Hanoi". Hoan Kiem Lake is the subject of major research project. Dredging Hoan Kiem Lake provides a large volume of sludge to be handled. As expected, in the implementation phase, 0.5 m sediments to be handled, an equivalent to 90,000 m^3 of water-slurry mixture. Through the press, about 9,000 tons of sludge were to be handled.

Other researches showed that if the density of bacteria in sludge is high, it could cause diseases especially if the density of coliform and fecal coliform is very high (10^3-10^4 MPN/g dry sludge). Therefore, prior to discharge into the environment or reuse, sludge should be handled properly.

There are three basic methods for handling sludge: thermal, anaerobic incubation and aerobic incubation. The thermal method uses heat energy to dry and burn the sludge. The advantage of this method is to treat sludge thoroughly. But the major drawback is the very high consumption of energy and high investment in technology. Anaerobic incubation method will use anaerobic microorganisms to decompose organic matter into methane. The advantage of this method is to generate methane used as fuels and electric heat. The downside of this method is the very high initial investment: the closed annealing tower, towers for air, gas fired heating systems and electrical networks, electrical connections, etc. not matching the scale of the project.

Methods of aerobic composting (composting) are more appropriate. Wiley and Pierce (1955) represented the aerobic composting process in the following chemical equation:

$$C_pH_qO_rN_s . aH_2O + bO_2 = C_tH_uO_yN_w . cH_2O + d\,H_2O + eH_2O + CO_2 \quad [7]$$

Organic matter — Oxygen consumption — compost — evaporated water — produced water — produced CO_2

During incubation, oxygen is supplied sufficiently for aerobic microorganisms (bacteria, radiating bacteria, fungi and protozoa). These organisms decompose organic matter, releasing heat and creating humus complexes [1,4,7]. The method of brewing compost using strains of thermophilic aerobic organisms can solve the problem. During aerobic decomposition, thermophilic microorganisms will release energy, raising the temperature of the pile to 50-60^{o}C in 3-5 days. At this temperature, pathogens and helminth eggs are destroyed in sludge before use for leveling or as fertilizer for crops, to avoid spreading into the environment [2,5]. This is an environmentally friendly method, with a relatively low cost of treatment that can be applied to a large volume of sludge, which can be used after processing to fertilize trees

2. Research methods

The purpose of the experiment is to find, on pilot scale (100 kg raw material per formula), the supplements and proper time for the aerobic biological composting of Hoan Kiem Lake sludge. Test design is based on some results obtained from experiments in the laboratory and inherited from the results of previous studies [3,4]. Before conducting experiments in composting, it is necessary to analyze the properties of the sludge. These include parameters such as pH value, moisture, N-total, C-total, C:N, weight.

Table 1. *Analysis of Hoan Kiem Lake sludge after treatment with belt press equipment*

No.	Indicators	Unit	Sludge
1	Total microorganisms	(CFU/g)	$1.5x10^{6}$
2	Total Coliform	(MPN/g)	1700
3	Fecal Coliform	(MPN/g)	1400
4	TOC	(mg/g)	72.3
5	COD	(mg/g)	270
6	Total Nitrogen	(mg/g)	7.9
7	Total Phosphorus	(mg/g)	2.0
8	Humidity	(%)	53.1

From the results in Table 1, the composition of nutrients in the sludge is too low, not conducive for microbial growth. Thus, sludge treatment by biological methods need to add carbon-rich material such as nutrients (e.g. rice straw, peat, rice husk ...), nitrogen and phosphorus. Such supplements also improve the structure of the sludge characteristics, facilitating better gas exchange in the pile. This property is a major impact on the process of composting, the impact of different adjuvant volume on the compost into the C: N ratio and improving the structure of the inputs in the laboratory and pilot study. In the framework of this paper, the author reported only the results of pilot-scale studies.

Materials:

- Sludge recovered from Hoan Kiem Lake using German technology, separated from water, moisture of 53.1% (later referred to as "HHK sludge").
- Microorganisms: thermophilic microorganism preparations Biomix-1 from the Institute of Environmental Technology, Vietnam Academy of Science and Technology (Biomix-1 preparations include strains of *Bacillus subtilis* and *Streptomyces* radiating thermophilic bacteria for rapid decomposition of organic matter in high temperature conditions)
- Peat: Peat mine from Vinh Phuc province.
- Sources of carbon: Straw chopped 5-10 cm, rice husk.
- Nitrogen sources: Phu My fertilizer.
- Source of phosphorus: Lam Thao phosphate.

Methodology:

- Compost pile obtained by composting method.
- Analysis and assessment of microorganisms in soil and water (TCVN 6848-2007, TCVN 6168-2002).
- Chemical determination of total nitrogen (TCVN 8557-2010), total phosphorus (AOAC 958.01), TOC (using ANATOC II equipment of SGE), heavy metals (TCVN 6496-2009, TCVN 6496-2009, TCVN 6496-2009, TCVN 6496-2009).

Test design: Incubation experiments with Hoan Kiem Lake sludge using formulas as follows:

- Formula 1 (CT1): 100.0 kg HHK sludge, Biomix-1 1.0 kg, 0.2 kg phosphate and 0.1 kg urea.
- Formula 2 (CT2) HHK sludge 90.0 kg, 10.0 kg peat, Biomix-1 1.0 kg, phosphate 0.2 kg and 0.1 kg urea.
- Formula 3 (CT3): 96.0 kg HHK sludge, rice straw 4.0 kg, Biomix-1 1.0 kg, phosphate 0.2 kg and 0.1 kg urea.
- Formula 4 (CT4): 96.0 kg HHK sludge, straw 3.0 kg, 1.0 kg of rice husk, Biomix-1 1.0 kg, phosphate 0.2 kg and 0.1 kg urea.
- Formula 5 (CT5): 90.0 kg HHK sludge, peat 9.0 kg, 1.0 kg of rice husk, Biomix-1 1.0 kg, phosphate 0.2 kg and 0.1 kg urea.

Venue: Institute of Environmental Technology, Vietnam Academy of Science and Technology.

3. Results

Prior to the annealing process, we determined the moisture content of the substrate to be used for processing. The humidity of the substrate is determined by the method of drying to constant weight at 105^0C. Results are presented in Table 2 below.

Table 2. *Physical and chemical properties of input materials*

Material	Density (g/l)	Total N (%TM)	Total C (%TM)	C:N	Water capacity (Vol%)	Gas capacity (Vol%)	Hole ratio (Vol.%)	Solid ratio (Vol.%)
Straw	60	0.41	48.4	118:1	20.4	69.9	90.3	9.7
Rice husk	40	0.35	44.9	128:1	37.6	41.9	79.5	20.5

Temperature fluctuation

Results in Figure 1 showed that during incubation in Formula 1 (CT1) experiments using Hoan Kiem Lake sludge, added with Biomix preparations, urea, phosphorus, but no additional carbon. The temperature of the pile was almost unchanged compared to room temperature. There was no growth of aerobic microorganisms nor aerobic decomposition of organic matter, so virtually no energy was released (no difference in temperature between the pile and room temperature). As per formulas CT2, CT3, CT4 and CT5 in addition to additional Biomix1 microorganisms, nitrogen and phosphorus, carbon were added in different forms: peat, straw and rice husk. We noticed the apparent difference in temperature between the temperature of the pile and the room temperature, i.e. the growth and decay of organic matter in the pile to release energy.

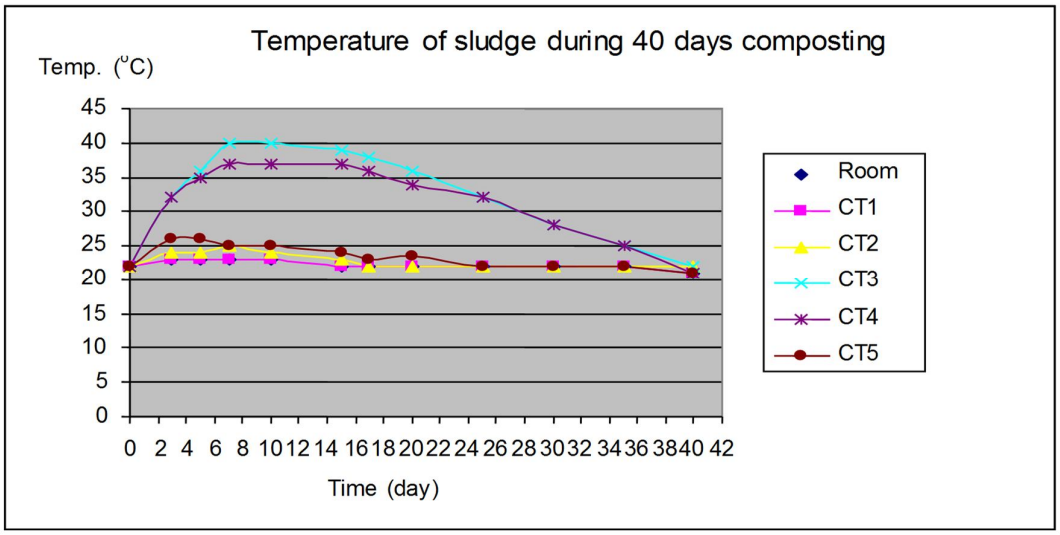

Figure 1. *Temperature during the 40 days of composting*

However, with the different types of substrate, decomposition occurs in different manners. In experiments CT3 and CT4, decomposition takes place in a better manner than CT5. Pile temperatures increased significantly compared to room temperature. Especially

in CT3, after one week annealing process, the temperature reached 40.5^0C and lasted for about a week when the pile temperature was gradually lowered.

Sludge quality after 40 days of composting

Table 3. *Analysis of sludge quality after 40 days of composting*

Indicator	Unit	CT1	CT2	CT3	CT4	CT5
pH	-	7.0	7.0	7.0	7.0	7.1
Humidity	%	56.7	56.4	58.2	57.3	57.0
OM	mg/g	285	302	365	370	315
TOC	mg/g	74.2	150	250	226	170
Total N	mg/g	12.5	17.5	18.6	18.0	18.6
Total P	mg/g	3.5	4.15	4.23	4.10	4.12
Cr	mg/kg	78.0	67.7	73.1	71.7	67.3
Mn	mg/kg	215	186.5	201.5	197.7	185.5
Cu	mg/kg	140	121.5	131.2	128.7	120.8
Pb	mg/kg	164	142	153.7	150.8	141.5
Fe	g/kg	19.50	16.92	18.28	17.93	16.82
Zn	mg/kg	589	511	552.1	541.6	508.1
As	mg/kg	12.3	10.7	11.5	11.3	10.7
Fecal coliform	MPN/g	1375	1050	310	450	870

Table 4. *Percentage of carbon and nitrogen in the pile before and after 40 days of composting*

	CT1	CT2	CT3	CT4	CT5
Begin	8.96:1	9:1	15:2	16.9:1	11:1
After 40 days	5.9:1	8.6:1	13.4:1	12.6:1	9.1:1

When comparing the results of Table 3 and Table 4, C: N ratio in all formulas changed after 40 days incubation, with a tendency to be smaller. This change is due to the decomposition of microorganisms and carbon usege as a source of energy and for cell formation [4,5]. Compared with the temperature changes, Figure 1 showed that in formulas CT3, CT4 and CT5, the carbon reduction was primarily by aerobic microorganisms. The pile heats up due to the temperature generated. In Formulas 1 and 2, the temperature difference between the pile and the room temperature is negligible. Thus, the reduction of carbon in this experiment is known to be caused by anaerobic microbial activities. This is consistent with the sensory evaluation when detecting bad smell in the formulas, especially in Formula 1 during the incubation.

The ratios of C:N in all formulas are less than 15:1. Moreover, the heat in the pile eventually was close to the ambient temperature, reaching a neutral pH, suggesting that compost in the formula [4,5] is "ripe".

General comments and discussions

Results in Table 4 and Figure 1 showed that:

- Using Hoan Kiem Lake sludge for composting will not be effective. But when organic matter such as straw, peat, nitrogen, phosphorus and microorganisms are added, it leads to an increase in the pile temperature enhance of the decomposition of organic matter of microorganisms and increasing the density of aerobic microorganisms.
- When the temperature in the pile is higher, the density of bacteria that can cause diseases (total coliform and fecal coliform) decreases. This can be explained by the strong development of the aerobic microbial organisms which compete with weaker species for food, which could inhibit or kill the weaker species. When the temperature of the pile is higher, it also became a factor hindering the development of other thermophilic bacteria.
- Comparison of the results of the analyzed compost after 40 days incubation with the quality standards for compost as specified in Decision 100/2008/QD-BNN [6] showed that some indicators such as humidity, fecal coliform exceeded prescribed limits. Those products do not comply with the standard and cannot be market-available.

4. Conclusion

From the results above the following conclusions were deduced:

- The sludge from Hoan Kiem Lake is poor in nutrients. For the composting of this sludge, substrates should be added to increase the amount of carbon, nitrogen and phosphorus.
- In the selected substrates to be added so as to increase carbon sources, investigations show that rice straw is a better material than rice husk and peat for the composting process with sludge.
- The addition of selected effective microorganism mixes accelerates the composting process and limits the growth of coliform bacteria and fecal coliform.
- After 40 days composting, the density of total coliform bacteria and fecal coliform reduces greatly but they cannot be totally eliminated. Therefore, it is recommended that after treatment, compost from sludge can be used as soil conditioner.

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