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Analysis of the Factors Influencing the Sludge Aerobic Microbial Compost Using Orthogonal Mode

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Abstract: Analysis of composting operation in different ratio of raw materials, ventilation and the turnover frequency under the condition of the orthogonal mode, the pile pile temperature can reach the set temperature of 60°C, hygiene index of compost product can reach the national standard of harmless. Through orthogonal experiment analysis, material ratio is about 60% moisture content, the ventilation is mixed with forced ventilation and natural ventilation day turning frequency time can speed up the pile of reducing the material moisture content and degradation of organic matter, the whole composting process does not need to sludge compost for regulating pH value.

Key words: Sewage sludge, aerobic composting, orthogonal mode

INTRODUCTION

City sludge is a general term of city sewage treatment plant in the purification of wastewater generated in the process of primary sludge, sludge, digested sludge which does not include the grid slag grille and grit gravel. This contains heavy metals, pathogens, weeds and other harmful substances (Anonymous, 1995). Aerobic composting of sludge is the metabolic activity by aerobic microorganisms will be biodegradable organic matters in sludge to microbiological process of humic like biochemical transformation and stable, the final product of aerobic composting for compost, can be used as organic fertilizer in agriculture (Lottermoser, 1995). Compost maturity directly affects the compost quality and its scope of application, the main factors affecting the aerobic composting including material ratio, ventilation and the turning frequency (Furhacker and Haberl, 1995). The experiment with Zhengzhou municipal sludge compost material, sawdust, corn cob, straw as a conditioner, influence in the forced aeration composting device made by orthogonal test method of material ratio, ventilation and the turning frequency on the process of sludge aerobic composting. In order to obtain the control parameters for sludge composting, improve the quality and quality of sludge compost and provide technical support for the land utilization of sewage sludge compost.

MATERIALS AND METHODS

Experimental materials: Zhengzhou BaGang sludge treatment plant, sludge from city to use the basic properties of 81.04~83.23%: moisture content, organic carbon content 306.01~318.86 g kg^{-1}, total nitrogen content for 26.74~30.53 g kg^{-1}, C/N for 8.39~9.98. Conditioner is a corn cob and maize stalk truncated to 3~5 cm long, wood from Zhengzhou City, the local wood processing factory, the return sludge compost maturity after. Characteristics of various materials (Table 1).

According to the survey, this study used material ratio (volume ratio): sawdust corncob straw return sludge sludge::: 0.3:0.3:0.3:1:1::: sawdust; corn straw return sludge sludge: 0.5:0.5:0.5:1:1. According to the different mixing ratio, water content were 60.25, 55.24, 68.62 and 78.29% of the initial organic matter.

Experimental system of sewage sludge compost: Composting experiment system using the experiment of forced ventilation composting experiment system static chamber sludge, the experimental system is composed of static bin composting bins and storage bin, forced ventilation using centrifugal blower and air chamber, air chamber is arranged in the baffle and perforation plate, the uniform gas distribution function; the main equipment has a time controller, a temperature controller, a temperature

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Table 1: Compost material characteristics

Material	Moisture content (%)	Organic matter (%)	Bulk density (kg.m^{-3})
Sludge	81.04~83.23 (81.36)	61.19~66.52 (64.26)	552.58~658.50 (593.30)
Sawdust	11.78~34.33 (20.91)	83.19~98.83 (91.26)	205.35~251.35 (224.76)
Corncob	7.41~11.40 (8.75)	95.28~96.61 (96.01)	83.33~125.00 (105.83)
Straw	12.56~20.15 (16.36)	80.24~97.85 (89.05)	100.32~136.44 (118.38)
Return sludge	37.35~38.94 (38.15)	52.13~52.85 (52.49)	466.67~500.00 (483.34)

Table 2: Main equipment models parameters of experiment system

Equipment	Model	Parameters
Time controller	ZN48SS-1	Range 1~9999s
Temperature controller	XS Intelligent measuring instrument	9 cannel
Temperature sensor	JWBTemperature transmitter	/
Centrifugal blower	4-72	Flow 11.31 (m^3 h^{-1})

sensor, a centrifugal fan. The experimental system of main construction equipment size and parameters are shown in Table 2.

Control parameters in the composting process: In the course of the experiment, ventilation for the 2 ways, respectively (1) Positive pressure ventilation mode, in the initial stage of compost, a time controller to control the centrifugal fan (set of centrifugal fan 1~10 min, 20~120 min), according to the control temperature of different stacking the harmless health requirements set stack is 60°C, when the pile center temperature reaches the set temperature of 60°C, temperature controller to control the centrifugal fan for forced ventilation on pile and (2) Combination of natural and forced ventilation, the ventilation mode can be divided into two stages, in the first stage, the pile using natural ventilation, forced ventilation does not use the equipment; in the second stage, according to the pile composting conditions, temperature control conditions make the pile to harmless the health requirements set stack is 60°C, the center pile temperature reaches a preset temperature 60°C, temperature controller to control the centrifugal fan start forced ventilation, when the pile body core temperature below the set temperature, time control of centrifugal fan, forced ventilation on pile, ventilation for centrifugal fan 10~90 sec boot, shutdown, 20~60 min) made at a high temperature period, killing pathogenic bacteria (Stentiford,1996; Leton and Stentiford, 1990).

Composting process of turning frequency by two kinds of frequency, a pile of a day, a day two times (Finstein *et al*.,1983).

EXPERIMENTAL METHOD

According to the above analysis, the control parameters in the process of aerobic composting for 3 factors (ratio of raw materials, ventilation, turning frequency), each factor has two levels. Using orthogonal table L4 (2^3) for experimental design. The orthogonal experiment is shown in Table 3.

Table 3: Orthogonal experiment table

Factors/ experimental	Material ratio	Ventilation mode	Turnover frequency
1	0.3:0.3:0.3:1:1	Positive ventilation	Once a day
2	0.3:0.3:0.3:1:1	Mixed ventilation	twice a day
3	0.5:0.5:0.5:1:1	Positive ventilation	twice a day
4	0.5:0.5:0.5:1:1	Mixed ventilation	Once a day

Stack stack after 3~4 weeks and the pile body surface temperature to basically the same with the ambient temperature, feed storage, after entering the maturity. In the whole composting process, according to the different period of time, for the analysis of pile of the upper, middle and lower samples, respectively in compost. The distance from the top layer is 20 cm, the middle distance on top of 65 cm, the distance from the bottom 20 cm. After the collection of samples after pretreatment, mixing and sieving, pretreatment for the removal of wood, stones and other debris. After the screening of a fresh sample water content, organic matter, pH value, Colititre, killing ascarid eggs rate determination. Sludge compost test index in the process of pile temperature, moisture, organic matter, pH value, coliform value, the killing rate of Ascaris eggs.

RESULTS AND DISCUSSION

Pile temperature: In aerobic composting process, the temperature is the key influence factors of compost maturity and harmless control, high temperature is beneficial to compost harmless and stabilization. Figure 1 shows the different control methods of sludge compost pile body, the temperature change of 3 layers and change the ambient temperature conditions. Table 4 shows the variation of body middle temperature on sludge aerobic composting reactor with different control methods:

- Ventilation Experiment 1, 3 used for positive pressure ventilation, pile body middle temperature reaches the set temperature and are respectively 5.58d and 6.3d. The heating rate were 0.07 and 0.13°C.h^{-1}, pile body

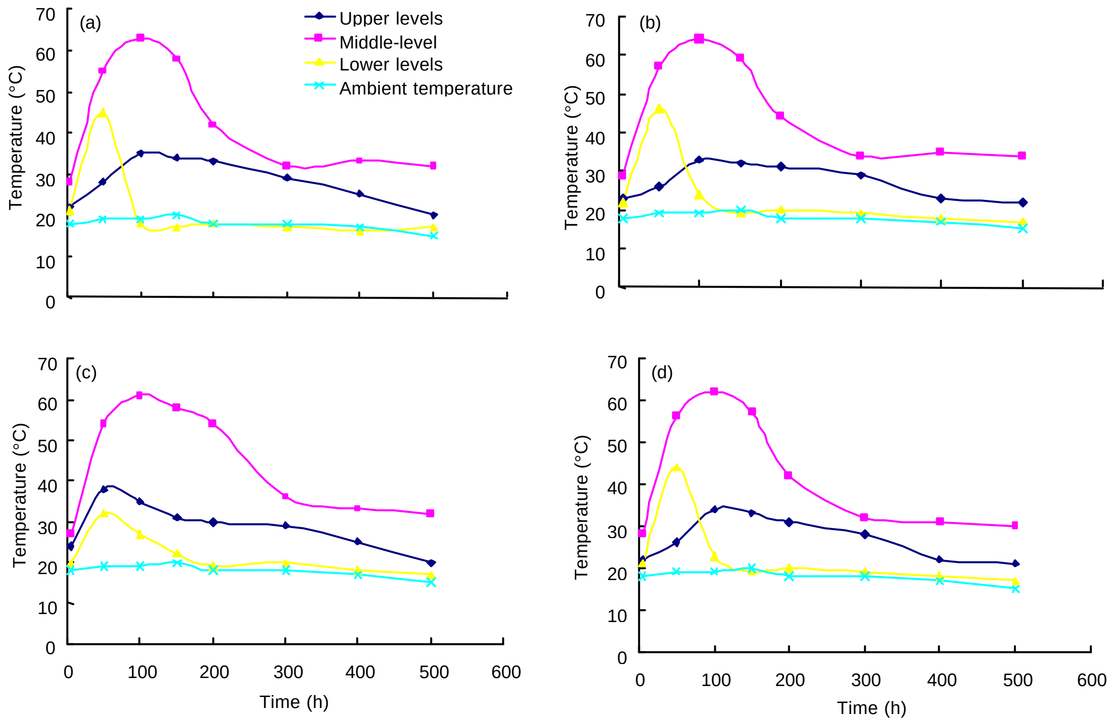

Fig. 1(a-d): Reactor temperature curve of different experimental parameters of sludge compost (a) Experiment one, (b) Experiment two, (c) Experiment three and (d) Experiment four

Table 4: Pile body middle temperature characteristics of sludge composting by using different control methods

Characteristic	1	2	3	4
Reactor temperature reached 50°C time required (day)	5.58	2.50	6.30	2.43
Reactor temperature >50°C time (day)	12.52	4.96	13.70	6.54
Maximum temperature (°C)	62.54	64.60	63.90	66.50
Reactor temperature to reach the highest temperature time required (day)	12.10	3.95	9.50	5.64
Heating rate (dT/dt/°C•h^{-1})	0.07	0.51	0.13	0.62

middle temperature higher than 50°C time, respectively for 12.52d and 13.7d, the highest temperature reached 62.54and 63.9°C. The highest temperature in the maturity stage can reach 70°C

- Experiment 2, 4, with natural ventilation and ventilation combining, experiment 2,4 reaches the set temperature, temperature reaches the setting time is 3.95 and 5.64 day, the pile temperature rise rapidly, heating rate, respectively is 0.51 and 0.62 °C.h^{-1}, pile body middle temperature greater than 50 °C time were 4.96 and 6.54 day, respectively, the highest temperature can reach 64.6 and 66.5°C

The experimental results show that, regardless of what kind of ventilation, the pile body middle temperature can reach the set temperature (60°C), high temperature and can maintain a certain time. Through the comparison of the 4 kinds of experimental reactor body adopts positive pressure ventilation and mixed ventilation, ventilation by mixing pile, pile pile temperature rise rapidly, experiment 2, 4 of the reactor body heating rate of Experiment 1, 3 times.

Water content and organic matter: Aerobic sludge compost water content under different conditions and organic matter in Table 5 changes in the characteristics of different composting stages.

At the end of the high-speed stage and maturity stage after water experiment, 1~2 was decreased in 17.06~18.34% and 46.52~48.03%, respectively, organic matter were decreased by 29.26~32.41% and 51.60~55.96%; the 3~4 water content decreased 12.27~16.55% and 40.51~43.45%, respectively, organic matter were decreased by 20.36~21.91% and 34.59~35.84%. From Table 4 shows: In the high-speed stage of composting, positive pressure ventilation can accelerate the reduction degradation and water content of organic matter in the sludge in the city; after the maturity

Table 5: Variation characteristics of sludge compost water content with different experimental parameters and organic matter

	Initial		High speed phase			After the maturity stage		
Serial No.	Water content (%)	Organic matter (%)	Water content (%)	Organic matter (%)	Change rate (%)	Water content (%)	Organic matter (%)	Change rate (%)
1	60.25	68.62	49.20	48.54	-18.34 (-29.26)	31.31	33.21	-48.03 (-51.60)
2	60.25	68.62	49.97	46.38	-17.06 (-32.41)	32.22	30.22	-46.52 (-55.96)
3	55.24	78.29	46.10	62.35	-16.55 (-20.36)	31.24	51.21	-43.45 (-34.59)
4	55.24	78.29	48.46	61.14	-12.27 (-21.91)	32.86	50.23	-40.51 (-35.84)

Table 6: Different experimental parameters of sludge compost health indicators

Index	1	2	3	4
Coliform value	0.43	0.11	0.32	0.09
The killing rate of ascaris eggs (%)	95	100	97	100

Table 7 Sludge compost energy using different experimental parameters

Serial No.	Total (kW.h)	Sludge (m^3)	Water content (%)	Time (day)	Dry sludge energy onsumption kW.h/(t.d)	Wet sludge energy consumption (W/t)	Ventilation mode
1	19.4	2.8	60.25	21	2.84	23.2	Positive ventilation
2	1.6	2.1	60.25	21	0.23	2.5	Mixed ventilation
3	10.9	1.2	55.24	21	2.11	31.2	Positive ventilation
4	5.3	2.5	55.24	27	0.55	5.5	Mixed ventilation

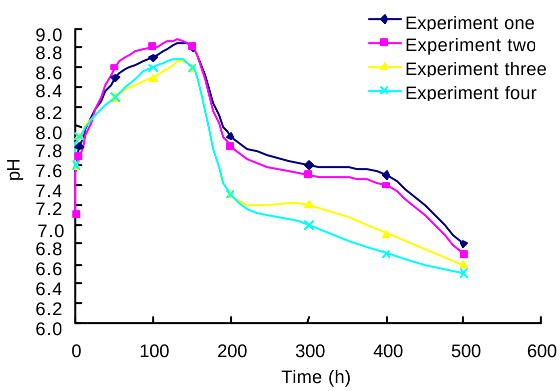

Fig. 2: Different experimental parameters of sludge compost

stage aerobic composting process, the sludge moisture rate continued to decline, according to city sludge experiment data by using the first material ratio than using city sludge second kinds of material ratio, water content in compost process to reduce the rate of high rate, organic matter degradation rate is faster. From Fig. 2 and Table 3 shows, affect the composting sludge water sewage sludge composting process rate, high water content and low were adversely affecting composting, about 60% water content in the composting process is more favorable. More conducive to rot maturation and stabilization of the compost.

pH value: According to the conclusion of the research of compost, sludge and bulking agents mixture pH value should be between 6~9, Fig. 2 shows the variation of the city sludge conditioner pH value during the composting process. Before stack to achieve higher temperature in the whole composting, microbial product stack body the new supersedes the old., is the main component of organic acid to the pile of pH decreased, with the sludge pile high temperature period, organic acid metabolites the volatilization and decomposition of organic nitrogen into ammonia caused sludge composting pH rose gradually, by comparing the temperature change curve and sludge composting, composting process can be obtained by using different material ratio, pile pH value appeared in high temperature composting process. Experimental study on the city of sludge compost the composting process show that, with different materials and different control parameters change, the pH values were between 6~9, not in the composting process on the stack, pH value is adjusted, in the normal course of composting of sewage sludge, sludge composting pH values in the composting process have a rise in temperature in the maturity stage, after the sludge pile body will tend to the neutrality.

Health indicators: According to the stool harmless sanitary standard (GB7959-87) (USEPA,1985), when the composting pile temperature up to 50°C for 5~7 day, fecal coliform value is 0.01~0.1, the killing rate of Ascaris eggs 95~100%, Table 6 shows that the hygiene index with different materials and different control parameters of sludge compost product. From Table 5 shows, the compost product can reach the national standard requirements.

Energy consumption: The composting process, different ventilation mode, ratio of raw materials, energy consumption is not the same. Table 6 shows that the energy consumption of the pile with different experimental parameters. The positive pressure ventilation, energy consumption (sludge was 2.11~2.84 kW/t.d); hybrid ventilation natural ventilation and ventilation combined, the unit energy consumption of sludge is 0.23~0.55Kw.h/(t.d). The experimental study shows that the energy consumption, sewage sludge compost using mixed ventilation sludge compost energy consumption of natural ventilation and ventilation combined with positive pressure ventilation than low.

CONCLUSION

- Using different experimental parameters for compost experiment, the pile pile temperature can reach the set temperature (60°C) and can keep a long time high temperature period, health index of compost product can reach the standard of harmless
- Same ratio mixed ventilation stack by positive pressure ventilation of the sludge pile body and the use of natural ventilation and ventilation combining the sludge pile, pile using mixed ventilation of sludge, the pile temperature rise faster, lower energy consumption, removal of positive pressure forced through wind speed pile moisture the removal rate of organic matter
- Sludge compost pile turning frequency body once a day, more conducive to rot maturation and stabilization of compost
- Through experiments using different material ratio experiment, should not be too low water cut pile rate, low moisture content is not conducive to the pile body and pile composting temperature. The water rate of 60% was more suitable for composting. In the process of city sludge compost pile, no need to adjust the pH

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