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ANAEROBIC COMPOSTING OF SOLID WASTE IN BATCH-LOADING DIGESTERS

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ABSTRACT

Pilot-scale experiments were conducted to study the anaerobic composting of food waste mixed with hay, and organic commingled waste mixed with septage. Location of this study was the Suranaree Military Camp in Nakhon Ratchsima City in northeastern Thailand. Hay was mixed with the food waste in a 1/0.34 ratio by volume (1/4.54 ratio by weight), and septage was mixed with the organic commingled waste in a 1/7.06 ratio by Volume (1/1.58 ratio by weight). Out of a total of four composting runs, the first run was carried out for 90 days, and the other three for 100 days each. Initial C/N ratio was kept at 25-30/1. Maximum temperature during the anaerobic composting process in the four runs ranged between 52-60°C and was achieved within three days from the start-up time. C/N ratio of the end product ranged between 13.9-18.5. A total coliform bacteria kill was achieved in the range of 99.81-99.99%.

INTRODUCTION

All communities have wastes. Be they wastewater, municipal solid waste, industrial or agricultural wastes, the community must deal with them. Costs to dispose of wastes, particularly municipal solid wastes, are escalating. Waste generated in a community can be a valuable energy and material resource; however, past and current waste disposal and treatment practices consume energy and have led this resource to become a serious environmental burden. In many areas, landfills are approaching capacity and closing, and new sites for the disposal of solid wastes are not available.

Anaerobic composting for recycling the biodegradable organic fraction of solid wastes generated is one good option for waste disposal. It is the decomposition that occurs using microorganisms that do not require oxygen. Although this is not the ultimate solution for the safe disposal of the solid wastes generated, it provides one useful end product: compost [1].

It should be noted that, in contrast to wastewater treatment, the terms "aerobic" and "anaerobic" for composting have relative meanings. They simply indicate what conditions are predominant in the process. As the compost materials are heterogeneous and bulky in character, in a compost heap there always exist "anaerobic" conditions, which are low in "aerobic" composting processes but abundant in "anaerobic" ones—and vice-versa for "aerobic" conditions. Some composting processes, such as composting pits as practiced in China, are aerobic at first and become anaerobic during the later stages of the composting period [2].

According to Gotaas, there is considerable interest in composting as an economical method for the disposal and reclamation of organic wastes in many parts of the world [3]. As for aerobic versus anaerobic process, there is little information on the bacterial species active in anaerobic composting, although several investigations concerning the bacteria involved in anaerobic digestion of sewage sludge have been made [4]. Probably, more species of bacteria are involved in the aerobic process than in the anaerobic one. There may be less tendency to lose nitrogen in anaerobic composting because of the lower temperatures, but the problems of odor nuisance, fly-breeding, and poorer destruction of pathogens are important disadvantages of anaerobic composting in piles. In a study on anaerobic digestion of solid wastes, different kinds of animal manure, water-hyacinth, and grass were used as feeding materials to produce biogas [5]. In a study on the biomass and biological activity during the production of compost, it was observed that in all composting processes, the aerobic and/or anaerobic breakdown of solid organic matter by microorganisms was the crucial step [6]. Few other research studies have been reported on the anaerobic composting of various kinds of organic solid wastes [7-12].

This study investigated the potential of anaerobic composting as a safe disposal method for organic fractions of municipal solid waste at the Suranaree Military Camp, situated in Nakhon Ratchasima City in the northeastern part of Thailand. The solid waste generation sources in this camp are mainly from residences of military personnel and their families, and offices located within the camp. The wastes at this camp are managed by the military with open dumping and burning in a large area inside the camp. Such disposal of solid waste is no doubt, highly objectionable from public health and environmental point of view.

The objectives of this study were to study the anaerobic composting process for the biodegradable organic fraction of solid waste from the camp, compare the rate of composting for two waste combinations (food waste mixed with hay, and organic commingled waste mixed with septage), and evaluate the suitability of the end product-compost as a soil conditioner based on bacterial die-off and changes in other characteristics during the process.

This study classified the initial wastes and analyzed the physical, chemical, and biological characteristics of the waste samples at the beginning and end of four simultaneous composting runs for the two waste combinations. Parameters included: moisture content, temperature, acid-base value (pH), carbon, nitrogen, phosphorus, and total coliform bacteria. The progress of the composting process for both types of solid waste combinations was investigated in analyses of composted material that met the final-product testing standards. The time period required for the composing of both waste combinations with a C/N ratio of 25-30/1 was also evaluated.

MATERIALS AND METHODS

Experimental Set-Up

Eight bricks digesters, 1.0 × 0.5 × 0.5 m (see Figure 1), were used in this study. Four digesters were for composting of food waste mixed with hay, and the other four were for composting of organic commingled waste (except food waste) mixed with septage. Gas outlets were provided in the lids of the digesters made with

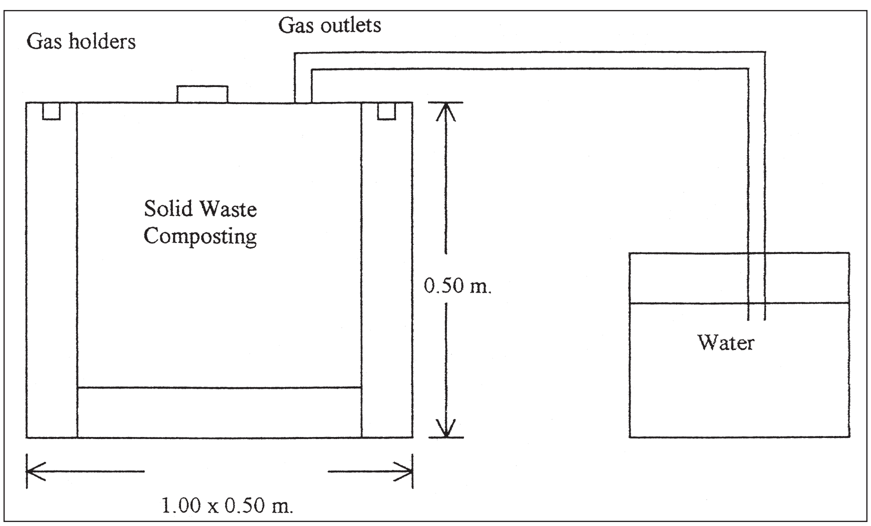

Figure 1. Schematic layout of the composting digester.

zinc (Figure 2). Each digester had a 0.02 m wide channel along its periphery, filled with water to provide a seal.

The solid wastes were collected daily from Suranaree Military Camp in Nakhon Ratchasima and separated manually into two categories: 1) food-waste and 2) organic commingled waste. Food waste and organic commingled waste (except food waste) were ground into 1 to 1.5 inch pieces. These were then mixed with hay and septage, respectively, in the proportions shown in Table 1.

The two combinations (food waste mixed with hay, and organic commingled waste mixed with septage) were then loaded into four digesters each as shown in Figure 3. The lids of the digesters were closed.

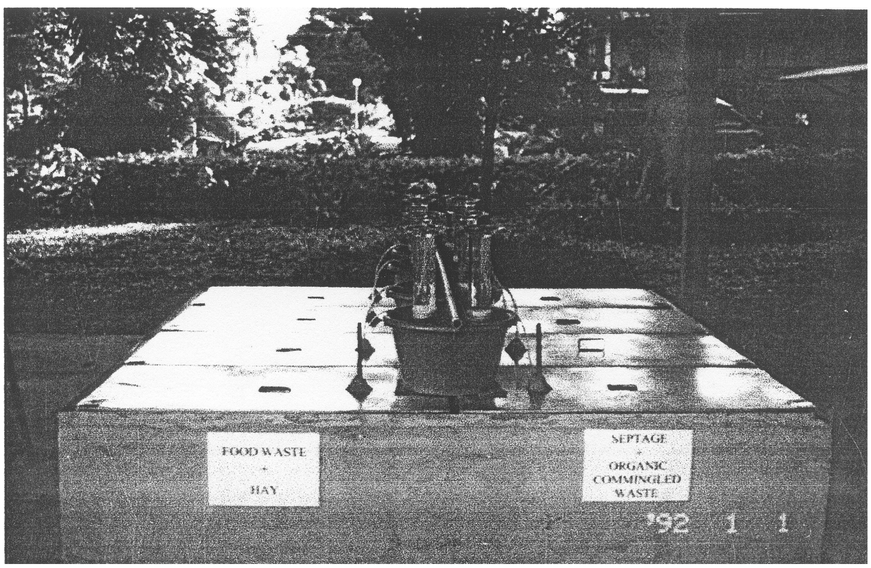

Figure 2. The front-view of the experimental setup.

Table 1. Proportions of Raw Material of Two Waste Combinations Used for Composting (Wet Weight Basis)

Waste combination C/N ratio 30 : 1	Ratio by volume (L : L)	Ratio by weight (kg : kg)
Hay : Food waste	167.83 : 57.17 = 1 : 0.34	14.10 : 64.03 = 1 : 4.54
Septage : Organic commingled waste	27.92 : 197.08 = 1 : 7.06	27.50 : 43.36 = 1 : 1.58

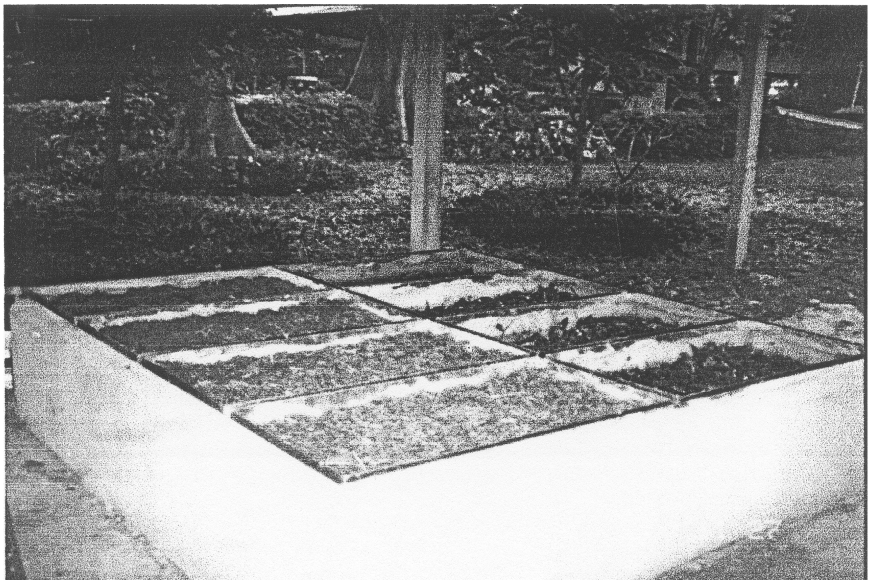

Figure 3. Top view of the loaded digesters.

Plan of Experimental Runs

Four experimental runs were made during a period of 5 months and 17 days (November 26, 2000–May 13, 2001). As the process had to be anaerobic, once the digesters were loaded, they could only be opened at the end of the run. However, it was also desired to follow the gradual change of various physical, chemical, and biological parameters of the composting material during the run. Therefore, the four runs were planed as described below.

After determining the initial parameters of the composting waste materials, all eight digesters (four for each waste combination) were used for Run I. Thereafter, two digesters (one of each waste combination) were opened in succession after 20, 40, 60, and 90 days, respectively. At these times, each group of two opened digesters was refilled with the corresponding waste combinations to initiate Runs II, III, and IV in turn. Thus, Runs II–IV were started at different times after the parameter analyses for the composted materials of Run I were carried out at the 20, 40, and 60 days, milestones. However, for these three runs, parameters were analyzed only at the beginning and end of the composting periods.

RESULTS AND DISCUSSION

The initial physical and chemical characteristics of the four fractions of raw material are summarized in Table 2.

The initial and final values of the 10 physical, chemical, and biological parameters of the two composting waste combinations during the four runs are shown in Tables 3 and 4, respectively.

Temperature

Hourly variations in the temperature were monitored during the first 72 hours of the third run as shown in Figure 4. The initial temperature of both waste combinations was 27°C. Subsequently, it rapidly increased to 54°C within the first 28 hours of composting for waste combination 1, and to 59.5°C within the 27 hours of composting for waste combination 2. From this point onwards, the temperature started decreasing. After three days, the temperature had reached to the ambient air temperature level (32°C). The final temperatures after 100 days of composting were 31°C for both waste combinations.

Composting Rate

The decomposition rate of the compost materials during the Run I was measured by observing the percent reduction of the organic carbon with time as shown in Figure 5. For waste combination 1 (food waste mixed with hay), the carbon content was 40.73% at the beginning and decreased to 38.78%, 35.98%, 33.35%, and 32.02% after the intervals of 20, 40, 60, and 90 days, respectively. For waste combination 2 (organic commingled waste mixed with septage), the carbon content was 33.60% at the beginning and decreased to 30.78%, 25.65%, 24.26%, and 23.12% after the intervals of 20, 40, 60, and 90 days, respectively.

For the organic commingled waste (except food waste) mixed with septage, the rate of decomposition of organic carbon was higher than the food waste mixed with hay. This can be seen through the comparison of the rate of decrease in both combinations of composted materials. The rate of decomposition ultimately

Table 2. The Physical and Chemical Characteristics of Raw Material to be Composed

Raw material	% TS	% TVS	% Moisture	% C	% N
Food waste	15.87	93.32	84.13	51.84	2.07
Hay	45.00	76.74	55.00	42.63	0.84
Organic commingled waste	54.87	93.97	45.13	51.87	1.51
Septage	18.06	65.71	81.94	36.51	2.30

Table 3. Initial and Final Characteristics of the Waste Combination 1 (Food Waste Mixed with Hay) during the Four Runs

No.	Parameter	Run 1		Run 2		Run 3		Run 4	
		0 day 26/11/00	90 days 24/02/01	0 day 20/12/00	100 days 30/03/01	0 day 06/01/01	100 days 16/04/01	0 day 02/02/01	100 days 13/05/01
1	Temperature	27	30	27	31.5	28	32	28	29
2	pH	5.88	7.23	5.78	7.71	6.78	7.95	6.14	7.91
3	Moisture content (%)	67.53	43.24	61.49	46.16	54.04	48.69	59.81	47.21
4	Total Solid (% TS)	32.47	56.76	38.51	53.84	45.96	51.31	40.19	52.79
5	Volatile Solid (% TVS)	73.31	57.64	73.75	41.00	78.66	45.06	70.40	40.95
6	% C	40.73	32.02	40.97	22.78	43.70	25.03	39.11	22.75
7	TKN (% N)	1.34	1.73	1.37	1.63	1.48	1.69	1.25	1.45
8	C/N ratio	30.39	18.51	29.91	13.97	29.53	14.81	31.29	15.69
9	Total Phosphorus (% P)	0.13	0.22	0.14	0.20	0.15	0.20	0.13	0.21
10	Total Coliform bacteria (# cell/mL H_2O)	1.37×10^6	3.31×10^2	1.31×10^6	2.34×10^3	2.11×10^6	4.07×10^3	1.52×10^6	1.87×10^3

Table 4. Initial and Final Characteristics of the Waste Combination 2 (Organic Commingled Waste Mixed with Septage) during the Four Runs

No.	Parameter	Run 1		Run 2		Run 3		Run 4	
		0 day 26/11/00	90 days 24/02/01	0 day 20/12/00	100 days 30/03/01	0 day 06/01/01	100 days 16/04/01	0 day 02/02/01	100 days 13/05/01
1	Temperature	27	30	27	31	27	31	27	28
2	pH	7.50	7.68	7.44	7.43	7.84	7.62	7.8	7.75
3	Moisture content (%)	72.03	45.64	67.56	56.44	61.7	46.02	65.48	48.53
4	Total Solid (% TS)	27.97	54.36	32.44	43.56	38.30	53.98	34.52	51.47
5	Volatile Solid (% TVS)	60.48	41.62	59.56	52.88	64.11	53.89	57.05	45.73
6	% C	33.60	23.12	33.09	29.38	35.62	29.94	31.69	25.41
7	TKN (% N)	1.08	1.62	1.15	1.73	1.19	1.7	1.09	1.53
8	C/N ratio	31.11	14.27	28.77	16.98	29.93	17.61	29.08	16.60
9	Total Phosphorus (% P)	0.08	0.20	0.12	0.22	0.10	0.23	0.07	0.20
10	Total Coliform bacteria (# cell/mL H_2O)	1.63×10^8	2.67×10^2	1.85×10^8	3.36×10^2	1.25×10^8	2.87×10^2	1.50×10^8	2.42×10^2

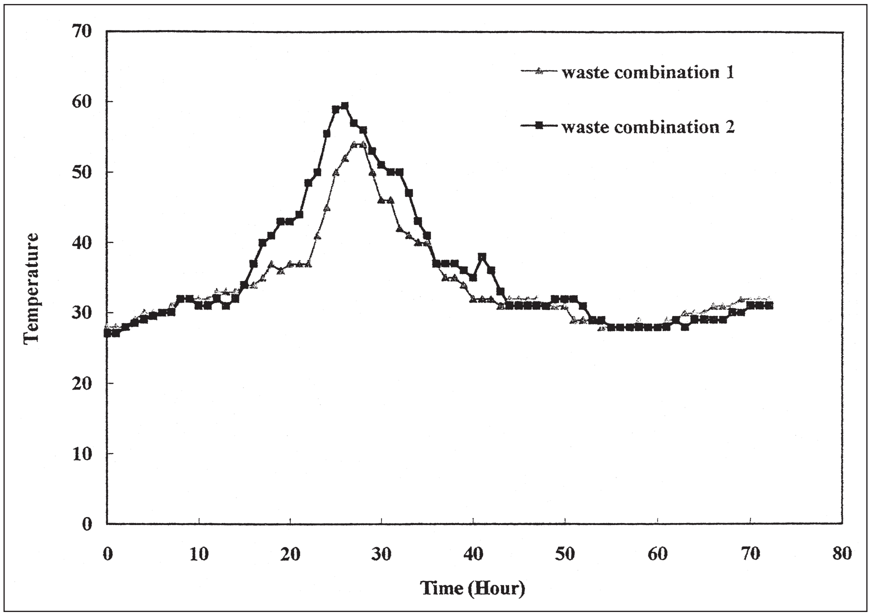

Figure 4. Hourly time variation curves of temperature during the first three days of Run III.

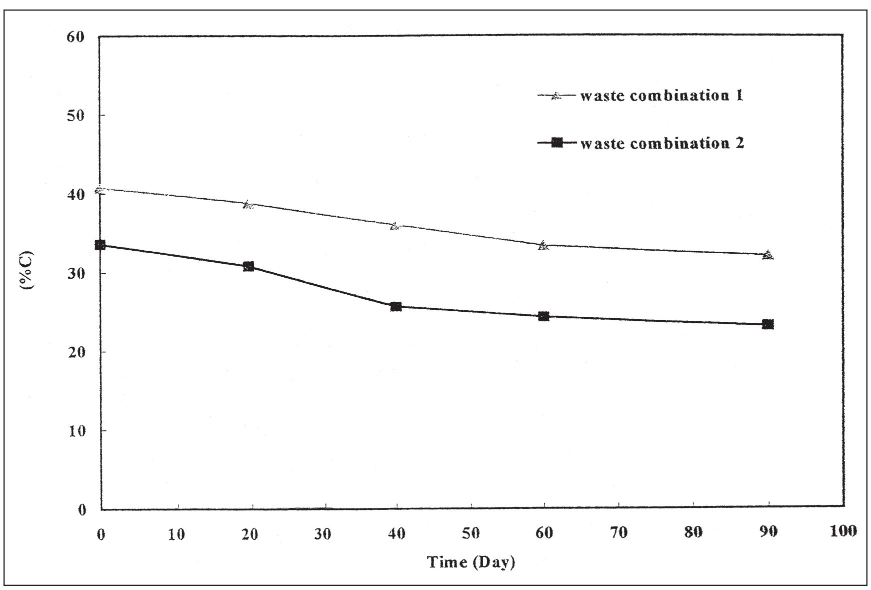

Figure 5. Time variation curves of carbon content during the Run I.

depends upon the capability of microorganisms to break down the materials by making appropriate use of oxygen added into system [4].

As the composting process progressed, the C/N ratio during the first run varied, as shown in Figure 6. For waste combination 1, the C/N ratio was 30.35 at the beginning and decreased to 29.19, 27.16, 22.37, and 18.54 after the intervals of 20, 40, 60, and 90 days, respectively. For waste combination 2, the C/N ratio was 31.05 at the beginning and decreased to 26.17, 24.65, 17.24, and 14.24 after the intervals of 20, 40, 60, and 90 days, respectively.

Nutrient Content

Nitrogen (N) and phosphorus (P) are the major nutrient elements responsible for the fertilizing quality of the compost product [13-15]. The variations in the nitrogen content as TKN during the first run are shown in Figure 7. For waste combination 1, the nitrogen content was 1.34% at the beginning and first decreased to 1.33% and 1.32% after the intervals of 20 and 40 days, respectively, and then increased to 1.49% and 1.73% after the intervals of 60 and 90 days, respectively. For waste combination 2, the nitrogen content was 1.08% at the

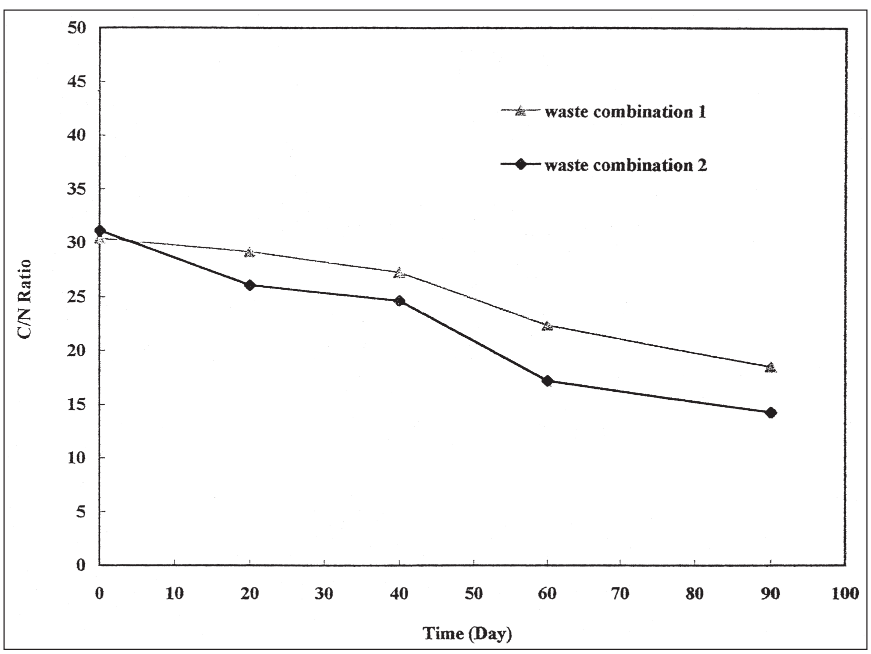

Figure 6. Time variation curves of carbon to nitrogen ratio during the Run I.

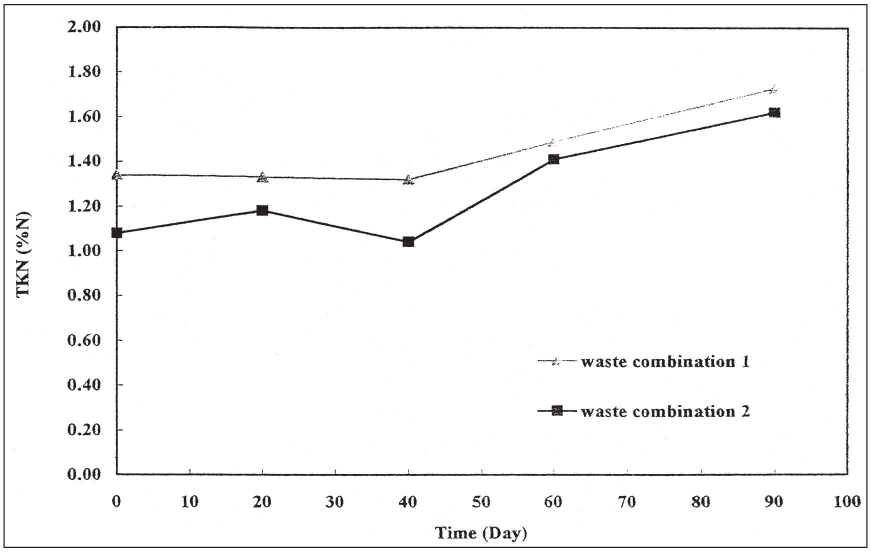

Figure 7. Time variation curves of nitrogen content during the Run I.

beginning and first increased to 1.18% after 20 days, then decreased to 1.04% after 40 days, and again increased to 1.41%, and 1.62% after the intervals of 60 and 90 days, respectively. While comparing the amount of nitrogen present in the both combinations of composted materials, it was noticed that waste combination 2 may have lost more nitrogen in form of NH_3 (gas) during the composting. Microorganisms utilize carbon and nitrogen at a ratio of 30/1. Low C/N ratio in feedstocks result in nitrogen volatilization in the form of ammonia.

The variations in the phosphorus content during the first run are shown in Figure 8. For waste combination 1, the phosphorus content was 0.13% at the beginning and increased to 0.19%, 0.21%, 0.21%, and 0.22% after the intervals of 20, 40, 60, and 90 days, respectively. For waste combination 2, the phosphorus content was 0.08% at the beginning and increased to 0.15%, 0.19%, 0.19%, and 0.20% after the intervals of 20, 40, 60, and 90 days, respectively. The phosphorus contents for each waste combination was inversely related to their respective final C/N ratio. The waste combination with a high C/N ratio had a low phosphorus content and vice versa.

Coliform Die-Off

The reduction in the total coliform bacteria (number/100 mL) during the first run is shown in Figure 9. For waste combination 1, the total number of coliform

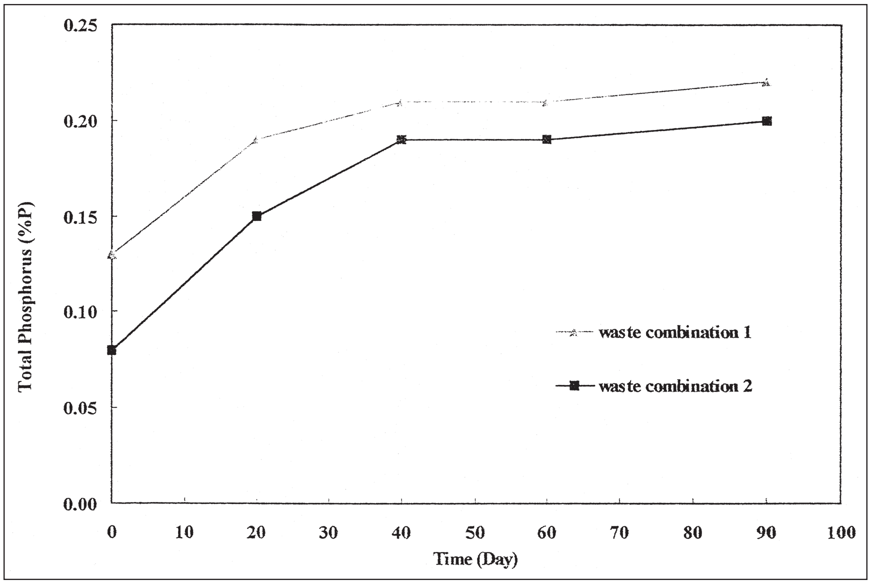

Figure 8. Time variation curves of phosphorus content during the Run I.

bacteria was 1.37×10^6 at the beginning and decreased to 2.67×10^5, 2.45×10^5, 2.06×10^3, and 3.31×10^2 after the intervals of 20, 40, 60, and 90 days, respectively. For waste combination 2, it was 1.63×10^8 at the beginning and decreased to 1.46×10^7, 6.90×10^6, 7.14×10^4, and 2.67×10^2 after the intervals of 20, 40, 60, and 90 days, respectively. Both combinations of composted materials had a reduction of 99.99% in total coliform bacteria in 90 days.

Since most studies in the literature have indicated a complete inactivation of the *Ascaris lumbricoids* eggs at the temperature of 50°C with an exposure time of two hours [3], no attempt was made to examine their survival in the composted material because the maximum temperatures were in the range of 52-60°C for about two days during the all four runs.

CONCLUSIONS

Anaerobic composting for recycling the biodegradable organic fraction of solid wastes is one good option for waste disposal. Although, anaerobic digestion of organic waste is also catching attention due to the high-energy recovery, anaerobic composting may score higher due to the several factors. One of them is that the effluents from anaerobic digestion are not generally suitable for putting directly

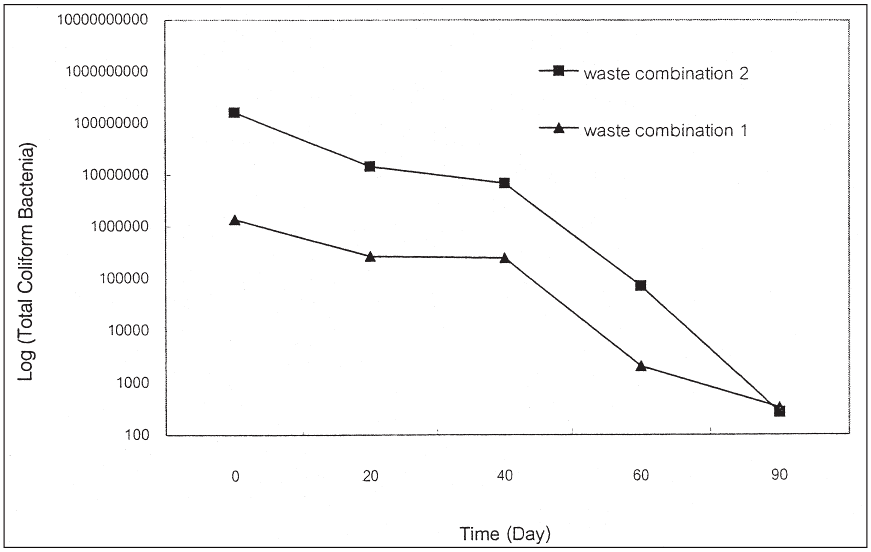

Figure 9. Time variation curves of total coliform bacteria during the Run I.

onto land. Post-treatment after anaerobic digestion is needed to obtain high quality, finished product. Thus, compared to anaerobic composting, anaerobic digestion is a complex process that requires larger investment. On the other hand, the end product of anaerobic composing of organic waste is directly applicable onto land.

Based on the results of this study, it could be concluded that anaerobic composting of the organic fractions of municipal solid waste at the Suranaree Military Camp in Thailand, mixed with hay and/or septage, could not only be a safe disposal method but also would provide a useful end product-compost. Further study is needed to evaluate the suitability of anaerobic composting for other organic waste compositions under a range of climates.

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