Educational Analysis of Compost Generated Through On-Site In-Vessel Food Waste Composting

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Introduction:

Environmental education seeks to teach traditional topics in new ways that link the students and their daily lives to the systems of life on earth. One of those key systems is how organic matter degrades and links humans to multiple biogeochemical cycles such as the food chain, carbon cycle and nitrogen cycle. In order to make these lessons pertinent and to simultaneously reduce the environmental footprint of the schools themselves many classrooms and schools are implementing foodwaste collection and in-school composting. Small scale composting systems provide hands-on experiences with solid waste systems, microbiology, soil attributes, organic matter impact, gardening, botany, and plant biology. Providing a composting system that meets the size, cleanliness, access, and security needs of a school is difficult and there are limited options.

The EarthTub™, manufactured by Green Mountain Technologies, is a student friendly system that is sized for kids to be involved with. There are very few options for thermophilic composting at this scale that are contained enough for use on foodwaste in a school.

The EarthTub operates in a continuous mix mode rather than the more traditional thermophilic batch, or plug flow composting method. The continuous addition of food and bulking material has been observed to work at relatively low temperatures which indicate a different suite of microbes may be performing the decomposition. Information about the characteristics of the compost produced is critical to the continued operation and expansion of in-school composting.

There is very little research available on small scale compost quality. A large amount of empirical information is available on the internet on the Earth Tub™ operation with respect to capacity and techniques of foodwaste collection in schools. Very little published research is available on such small scale systems and none on the compost quality resulting from these systems.

Compost quality is important to these small scale users so that they can use the compost for fund raisers and community outreach. Such projects provide funds for student activities, and also provide a learning avenue for the community as the schools interact with parents, local businesses, and community gardening groups. Such engagement can benefit the schools both energetically and financially.

With increased understanding of what actions impact the quality of the resulting EarthTub compost, the quality of these composts is expected to improve which will increase the potential uses for the finished compost. Improving the quality of the compost produced is also important for schools which use their compost in their gardens or landscaping. The success of the plants grown in the resulting compost becomes a visual reinforcement of the program beyond reduction of the garbage load and education value.

Figure 1. Washington State Department of Ecology Earth Tubs™ .

The phase of composting studied in this project that is related to compost quality is the curing, or stabilization phase. This phase covers the changes that take place after the compost has been removed from the Earth Tub™ and is allowed to passively decompose. This phase is defined by lower temperatures generally thought to be dominated by fungal degradation. The changes that occur during this phase have never been investigated relative to Earth Tub™ composts. Because of the importance of this stabilization period to the quality of the compost, we concentrated our investigation on this phase. Additionally, it is difficult for schools to optimize the management of the Earth Tubs™ during their 'active' food-addition phase because of the variability in the logistics of each school and their feeding routines. If the stabilization phase is augmented to improve the quality of variably produced compost, some of the pressure to manage the systems in a particular way during active composting could be reduced.

Earth Tub™ Operations:

An Earth Tub™ is a contained circular plastic tub with an electric-drive auger that is rotated around the bin manually to mix and aerate the compost. See Figure 1. The Earth Tub™ system consists of the mixing unit and bin, an aeration system and biofilter and a leachate collection system. The aeration is provided by pulling air from the base of the tub through a coarse layer of material placed in the bottom of the tub through the composting feedstocks above into the headspace of the bin; then, through piping and the fan into a separate biofilter container to treat odors. Leachate collected at the bottom of the tub is drained off to operator specific containment or use. The 3-cubic yard tub has a port in the lid that can be removed to add food waste and bulking material and water if needed. There are 2 doors in the sides of the tub for unloading the finished compost and maintaining the bin.

An Earth Tub™ compost batch is started by placing about 4-6 inches of coarse woody chips or hog fuel in the base of the tub as a plenum to help distribute the air and prevent clogging of the metal grate at the base. Green Mountain Technologies' Earth Tub™ Operations and Maintenance Manual (2003) recommends pine bark nuggets. On top of this layer at least a third to a half of the tub volume should be filled with high carbon bulking material such as hardwood shavings, leaves, or other similar material. Into this bed the food waste is added as it is generated. Water and additional bulking material are added as needed and the temperature is monitored to track the activity of the compost. Each time food waste is added, the auger is switched on and rotated around the bin to mix and aerate the food and bulking material. Once the bin is full or some other criteria determines that the Earth Tub™ batch is done, the material should remain in the tub with periodic mixing for at least 2 weeks to allow fresh material to degrade. At this point the Earth Tub™ may be emptied and the compost placed in a holding area to cure. Karin Grobe / Santa Cruse County Public Works has prepared a detailed set of recommendations to augment GMT's Operations Manual. That Supplement is provided in Appendix 5.

Methods:

In order to understand what factors are most important to the resulting compost, we enlisted the participation of 4 Earth Tub™ operators: Crestwood Elementary School; Waskowitz Environmental Leadership & Service Programs of the Highline School District; Willows Lodge; and Washington State Department of Ecology. At each operator's site the compost was taken from their Earth Tub™ when each operator normally emptied the Earth Tub™ and was placed in a stabilization ring. The stabilization rings consisted of 3-foot high woven mesh fencing with a diameter of about 4 feet and a volume of approximately 1.5 cubic yards. The rings were lined with a light breathable plastic fabric to help contain the smaller particles.

The rings were left to cure and mature for 24 weeks. Temperature was monitored on all Earth Tubs™ prior to transfer to stabilization rings. Compost samples were taken for testing when the stabilization ring was filled (time 0) and again approximately at 4, 12 and 24 weeks. Samples for testing were analyzed for select nutrients, pathogens, and agronomic indicators of compost quality (Table 1). At each sampling date, two representative samples were taken from the piles, the piles were turned and water was added as necessary and available.

Figure 2. Stabilization ring at Willows.

Methods used in this study are those generally adopted by the compost industry and specific methods can be found in Test Methods for the Examination of Composting and Compost, (US Composting Council). Nutrient methods are those from the Plant, Soil, Water Reference Methods for the Western Region, WREP 125.

Table 1. Analytes tested during 24-weeks of the stabilization period.

Nutrients	**Agronomic Indicators**	**Pathogens**
Ammonium-N	pH (1:5 method)	Salmonella
Total N,dry	Moisture content	Fecal coliforms
Total C	Electro-conductivity (1:5 method)	
C:N	Stability (Solvita method)	
Nitrate-N	Porosity	
Total P	Pea germination percent	
Total K	Cress germination percent	

The analytes measured in this experiment are indicators of compost quality and will dictate the appropriate use and probable success of using the compost for plant growth. Soil quality indicators can be broken down into several large categories, plant growth response, nutrient content, pH and soluble salts, presence of pathogens, maturity, and biological stability. Each indicator provides different information about compost quality or the appropriate use of the compost.

Figure 3. Contents of stabilization ring prior to sampling.

Plant growth response is an indicator of the specific plants tested. Some plants are better indicators than other for predicting compost effect. As compost becomes more stable it contains less phytotoxic compounds and plant growth is less inhibited by its application.

Soluble salts and pH are analytes that provide information on the plants and situations where the compost can be used. If the pH and soluble salts of specific compost are outside of an accepted range the compost application rate and/or use will need to be adjusted.

Maturity and biological stability are easily confused. Maturity is the measure of phytotoxic materials in the compost. Delayed germination is an example of a phytotoxic effect. Compost stability is the degree of biological stability which can be measured through the use of the Solvita™ test. The Solvita™ test provides a measure of CO_2 generation. The test suggests a use category based on both CO_2 and NH_4 generation. The test is accepted by various organizations as a good indicator of appropriate use of the compost.

Pathogens, fecal coliform and salmonella, are bacterial indicators of human disease carriers. These indicators were determined historically from the body of EPA research for biosolids management. Salmonella is often used when food or animal derived wastes are evaluated. Fecal coliform is ubiquitous in the environment and provides an indicator of how well pathogen reduction aspects of composting have worked.

Results:

The two Ecology tubs were well managed and temperatures reached above the PFRP level of 131°F during operation (Figure 5.). None of the other sites attained PFRP. PFRP is the Process to further Reduce Pathogens. It is a time and temperature relationship that is required for biosolids management and has been generally adopted by the composting industry for certain feed stocks PFRP for aerated static piles with a thermal cover is 131oF for 3 days.

Waskowitz, after struggling with excessive moisture, finally reached temperatures above 131°F but not for any consistent time periods. Crestwood's composting temperature vacillated between 40-100 ° for the entire composting period.

Volumes and types of food added were tracked at the different sites during the active composting phase (Table 2). Like the temperatures, the amount of food added varied depending on the facility (Figure 6.) Both weight and volume were recorded for 4 out of the 5 Earth Tubs™. Ecology composted over 2500 lbs or 600 gallons during a 64-71-day composting phase. Similar to Ecology's Earth Tubs™, Willows composted over 2500 lbs or 600 gallons of food waste during a 138-day composting phase. Crestwood and Waskowitz composted less intensively than the other two locations, but a similar amount of food waste, 1302 and 1458 lbs respectively, was processed over 147 and 229 days. Since both weight and volume of the foodwaste added were recorded at 4 of the 5 Earth Tubs™ , a conversion could be calculated (Figure 7.). It was surprising how similar the foodwaste densities were at the different facilities. The overall average was 1 gallon of food waste equaled 3.5 lbs.

Table 2. Summary of length of composting and food composted.

Facility	Length of Active Composting (Days)	Total Food Added (lbs)	Average food added daily* (lbs/day)	Active Operational Issues
Crestwood	147	1302	12	-
Waskowitz	218	1458	9	Too much moisture during composting
Willows	133	2634	28	Occasionally used animal manure w/ bedding
Ecology 1	64	2568	56	-
Ecology 2	71	3590	71	-

*Based on a additions 5 days/week

Total nitrogen during the stabilization period ranged from 1.5% to 4% (Figure 8). The two Ecology tubs had higher total N concentration, which made sense given the larger amount of high nitrogen food waste added during composting. Willows, with the second highest food waste intensity, also occasionally added manure with bedding to the Earth Tub™, which decreased the total N concentration.

Total C concentration was relatively stable during the stabilization period except for Willows' that measured much lower at the last sampling period (Figure 8.). The C:N ratio of Ecology's and Crestwood's composts were in a moderate range between 10:1 and 14:1 over the stabilization phase (Figure 9). Waskowitz's C:N increased in the 24-week sample, whereas Willows' generally reduced over the stabilization phase. Nitrate and ammonium concentrations of all of the composts were relatively low (less than 1200mg/kg) throughout the stabilization phase. (Figure 10.).

Both total phosphorus and total potassium generally increased during the stabilization period. This may be explained through the loss in volume during the stabilization phase. The levels of P and K ranged from 0.20%-0.5 %, 1.0%-2.1% respectively. (Figure 11).

Stability during the stabilization phase for willows, Crestwood and Waskowitz increased (became more stable) as would be expected. The two Earth Tubs™ at Ecology became less stable (more active) over time (Figure 12).

Moisture contents for the different Earth Tubs™ varied quite a bit during the stabilization phase 30%-70% (Figure 13). Controlling moisture during the stabilization phase was difficult because of the frequency of sampling/turning of the pile, pile location and ability to add water. The first Ecology stabilization period was under cover and received no additional water during stabilization, while the second was stored outside where it was exposed to rain. Both Waskowitz and Crestwood received additional water during stabilization phase.

Electrical conductivity, used to measure salts, ranged from1.5-8.2 mmhos/cm or dS/m during the stabilization phase (Figure 13). Compost with excessive amount of salts (values over 4 mmhos/cm) needs to be sparingly applied to gardens so plants don't develop toxicity symptoms. Only Ecology 1 showed an increase in electrical conductivity during stabilization.

The compost's acidity or alkalinity is measured by pH testing. The pH of composts in this study was generally more alkaline in nature with pH above 7. Crestwood's and the Ecology's compost decreased in pH during the stabilization period where the others remained about the same, on the alkaline side of neutral. (Figure 14).

Figure 4. Emptying Earth Tub™ at Willows

Germination of cress and peas are an indication of the usability of the material in the field and how plants respond to the compost. These composts generally produced adequate germination of the cress and lower germination in the peas. This is the reverse of usual results on compost with these two plants. Cress however is generally considered an indicator of compost usability. (Figure 15).

No salmonella was found in any of the composts during the stabilization phase of the experiment. Coliform bacteria measured during the stabilization phase of the experiment were found in composts at Waskowitz and Willows during the early stages of stabilization but were down to zero by the end of the stabilization period (Figure 16). These results points to good pathogen destruction during the active and stabilization phases of Earth Tub™ composting. Although under some circumstances the extended stabilization phase is needed for pathogen destruction.

Discussion / Conclusions:

This study clearly demonstrates that large amounts of food waste can be diverted by Earth Tub™ systems with proper management. In this study the amount diverted ranged from 1300-3600 lbs over as little as 64 days. Temperatures and management styles differed radically during the phase of food addition. Some locations did an excellent job of managing the Earth Tub™ to maximize composting and pathogen destruction. Some locations struggled with maintaining adequate temperatures and moisture contents. All sources of food waste averaged a weight of 3.5 lbs per 1 gallon of food waste.

Moisture levels during the stabilization phase were quite different depending on location and management. Comments from the different operators during the active phase describe some composts being either too wet or too dry for optimal composting.

C:N levels of finished compost fall into 3 different categories: low (<10), high(15-25), and woody (>30). Low C:N materials provide N readily for plant growth, high C:N provides slow N availability and is generally used as organic matter addition. Lastly, woody materials will tie up N when applied for plant growth and are better used as mulches. The composts in this study fell into the low or high C:N zone. They will provide N for plant growth, either immediately or over time. Available forms of N are nitrate and ammonium. Both were found in low levels in the Earth Tub™ composts. All locations had different C:N ratios at the beginning of the stabilization phase, but all were within a close range that would generally supply N for plant growth when applied to gardens.

Total P in theses composts were found in low levels, whereas K was found at higher levels.

The pH of the finished composts in this study ranged from 5.5 to 9.0. This is a very large range but should not be a problem when applied to the soil at relatively low levels and should not inhibit plant growth.

Electro conductivity is a measurement of soluble salts in the compost. Salts can be a problem at very low levels. The composts in this project ranged from low to quite high (from 2 to 8 $mmhos/cm^2$). Food waste has been reported to create one of the saltier composts. Because of this feedstock, application rates should kept low to avoid plant growth problems. Application rates should be kept to less than 1-inch deep on your garden.

Compost stability is a measurement of the biological activity of the compost piles. Good quality compost is usually described as having low levels of CO_2 activity. Low levels of biological activity can also be a symptom of composts that are either overly wet or overly dry. Either one will give erroneously low stability measurements. Both conditions may have occurred in this study. Generally, as composts age they become more stable. This was not the case in this study as three composts became more stable and two became less stable. The Earth Tubs™ that became more stable were less intensively managed. Those that had a higher level of food additions became less stable as stabilizing time increased. These results may be partially explained in that these composts may still have needed a more extended active phase to more fully degrade the more active forms of compost in the composts.

The pea and cress germination test in these composts was the reverse of what would generally have been expected. Cress is usually the more sensitive to immature compost than peas (Figure15).

Although coliforms were found at the end of the active stage (upon removal from the Earth Tub™) in several of the composts, by the end of the stabilization period the levels of salmonella and coliforms in all of the composts were at zero. These results from the pathogen testing point to good pathogen destruction during the active and stabilization phases of Earth Tub™ composting. For this reason, the extended stabilization phase can be a valuable tool for total pathogen destruction, regardless of management of the active phase.

The overall conclusion from this project is that large quantities of food waste can be safely and effectively diverted into a usable product for plant growth. Although during the 'in-vessel' phase of composting the basic tenets of composting (Table 3) should be adhered to such as managing porosity and moisture content, of the mix, and monitoring temperature closely. An extended phase in a stabilization ring can be beneficial in that increased curing was shown to increase compost quality. Although the Earth Tub™ system, because of its size, has the potential for large variability in compost parameters it still can produce usable compost in a relatively short period of time. The Earth Tub™ composted food waste in this study made compost with nutrient concentrations that will be beneficial to plant growth when applied to gardens. The one factor that arose as the main driver for application and use was the high salt content of the food waste compost. Application rates of this compost should be limited to no more than 1 inch deep to your garden to avoid plant growth problem due to salt toxicity.

Table 3. Reasonable and preferred ranges for optimum composting conditions

Parameter	Reasonable Range	Preferred Range
C:N Ratio	20:1-40:1	25:1-30:1
% Moisture	40-65%	50-60%
O_2 Conc.	> 5%	~10%
Particle size	1-3 "	< 1-2 "
pH	5.5-8.5	6.5-8.0
Temperature	131-170 °F	131-150 °F

Rynk, R. 1992 On Farm Composting Handbook. Natural Resource Agriculture and Engineer Service. NRAES-54.

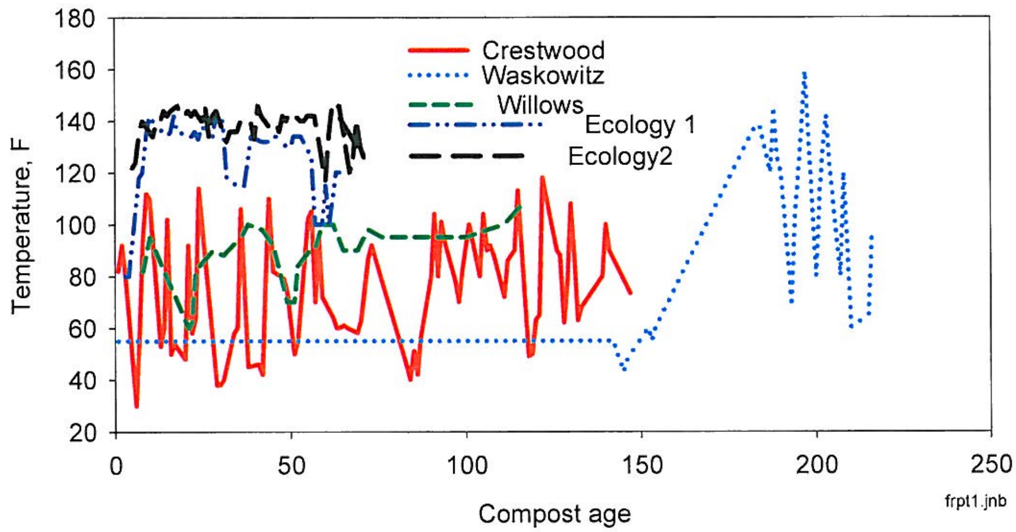

Figure 5. Temperatures of Earth Tubs™ during active phase of composting

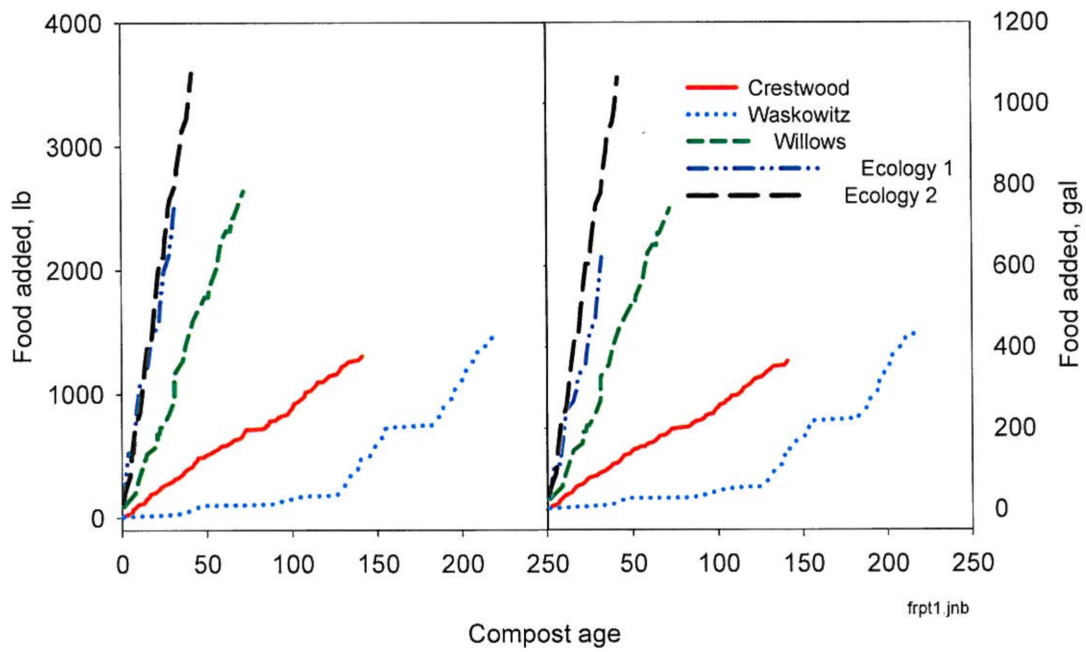

Figure 6. Earth Tub™ compost feed stock volumes and weights.

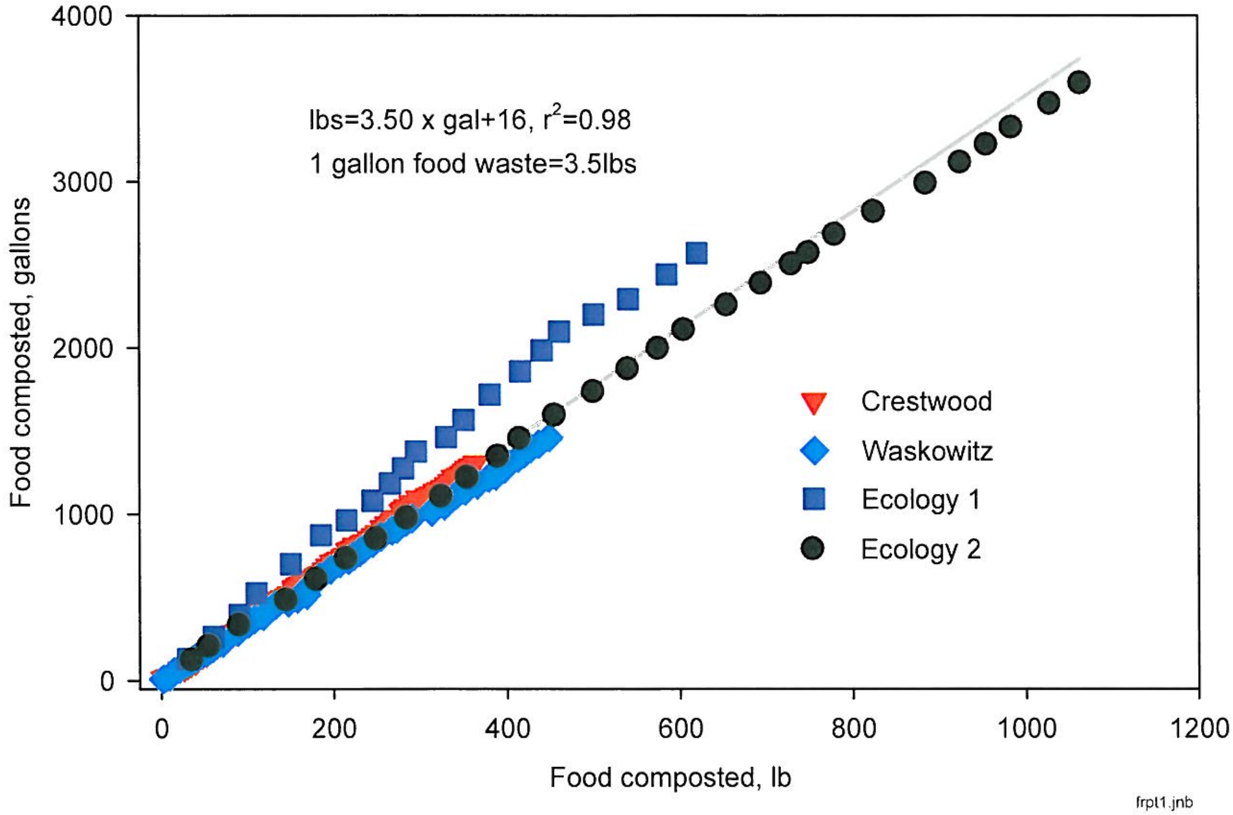

Figure 7. Comparison of feedstock weights and volumes.

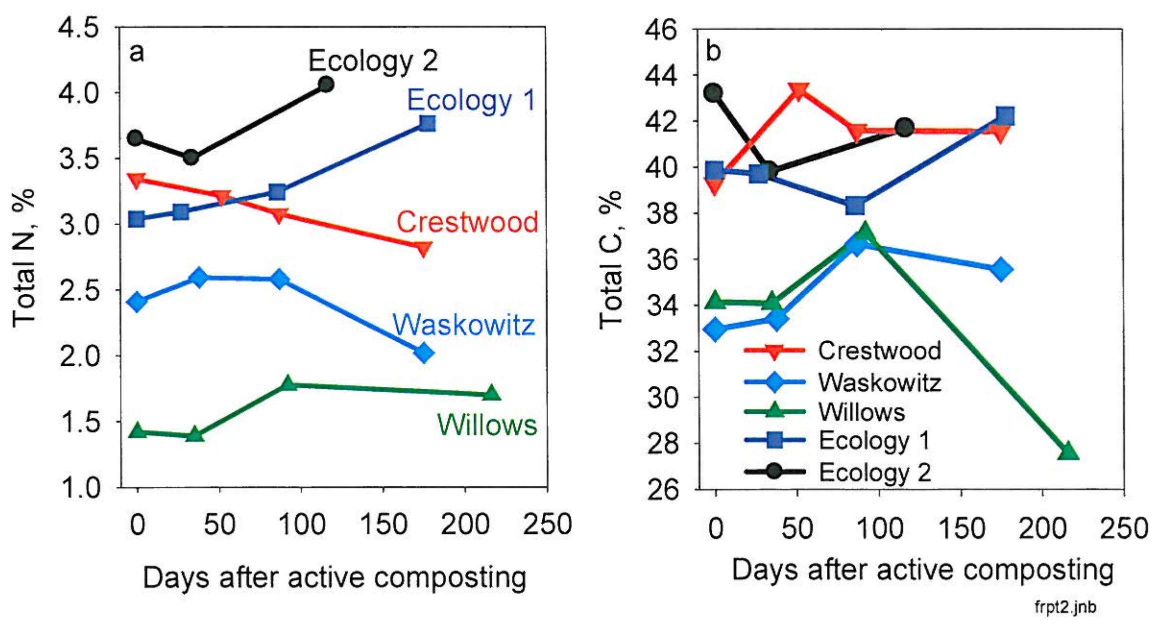

Figure 8. Total Carbon (a) and Nitrogen (b) during the stabilization phase of composting.

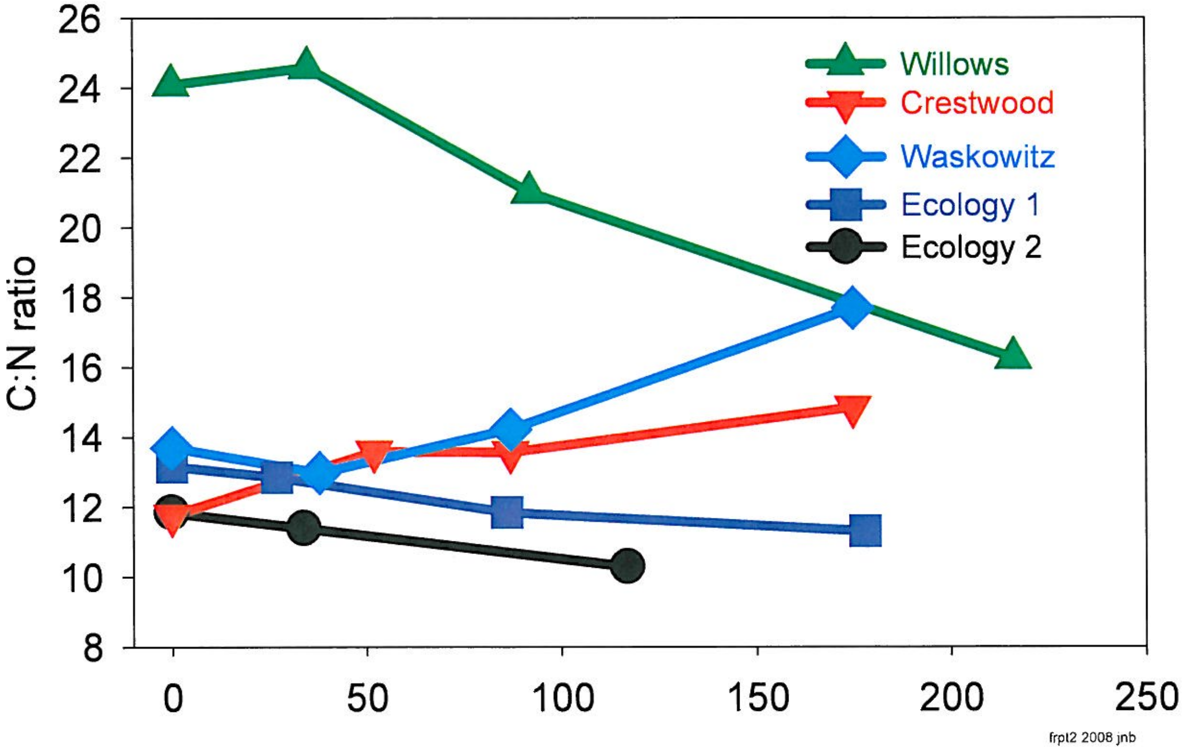

Figure 9. C:N ratio during the stabilization phase of composting.

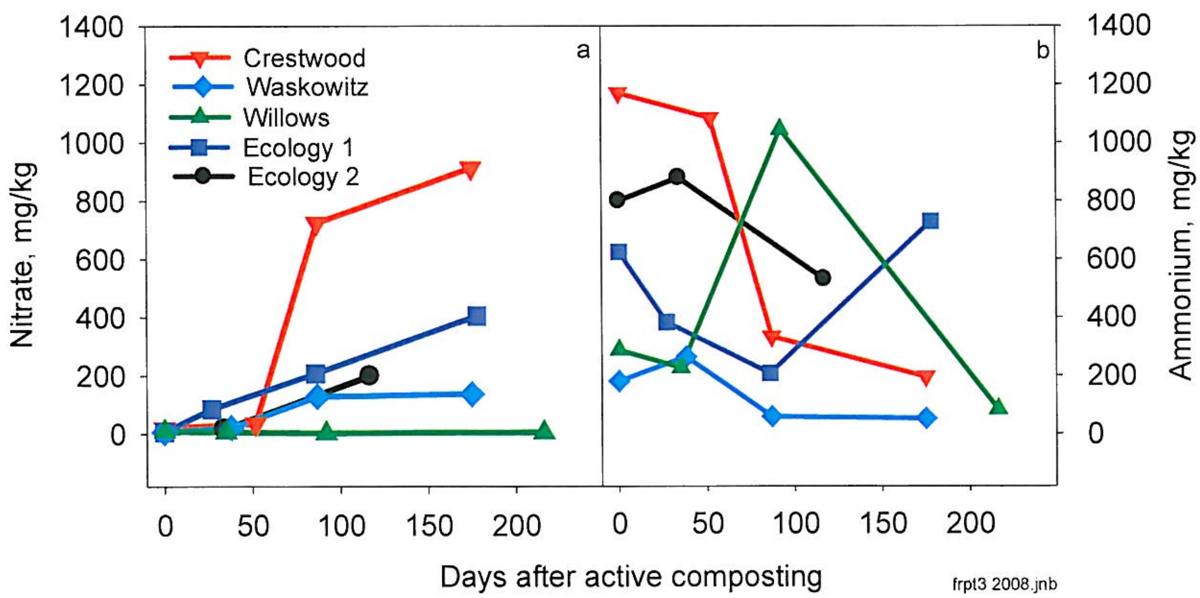

Figure 10. Nitrate (a) and ammonium (b) concentration of Earth Tub™ composts during the stabilization phase of composting.

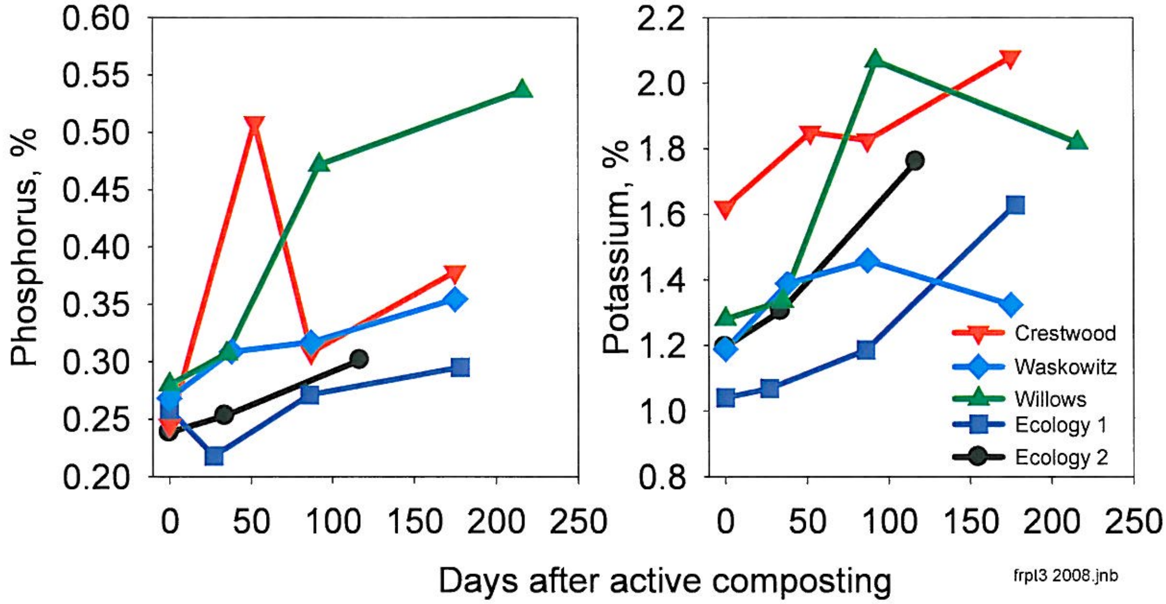

Figure 11. Compost total P and K during the stabilization phase of composting.

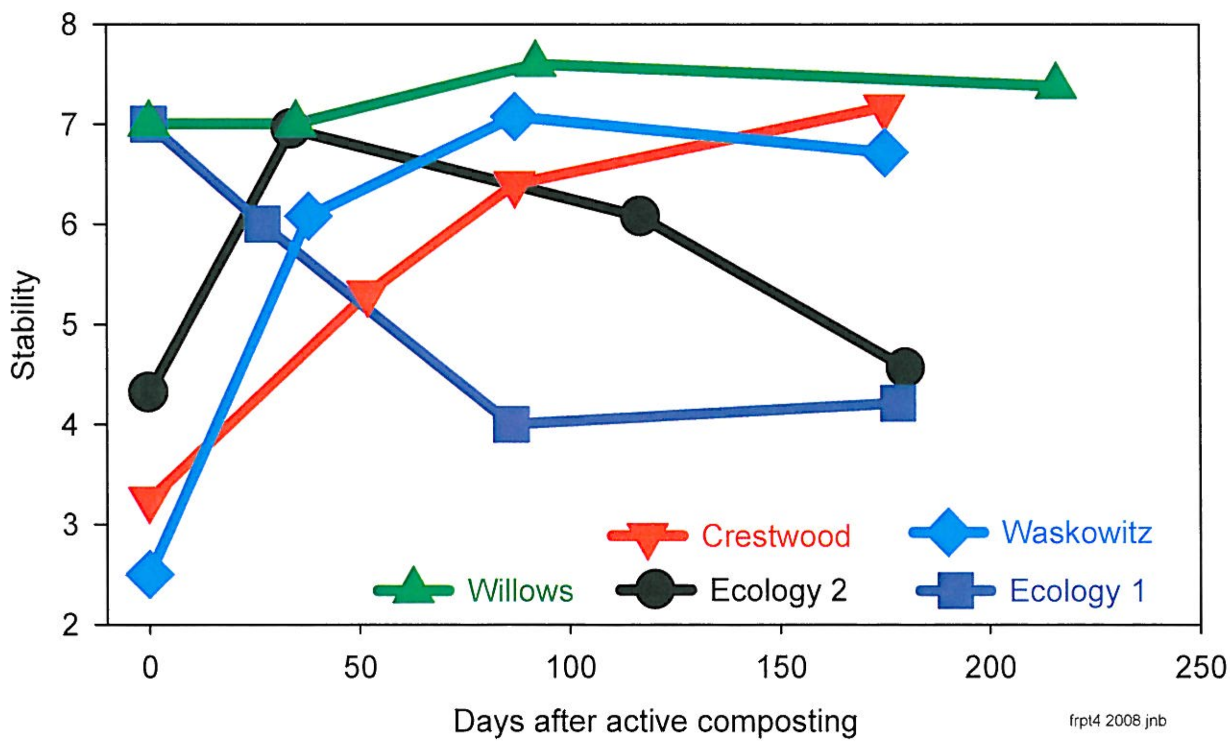

Figure 12. Compost stability during the stabilization phase of composting.

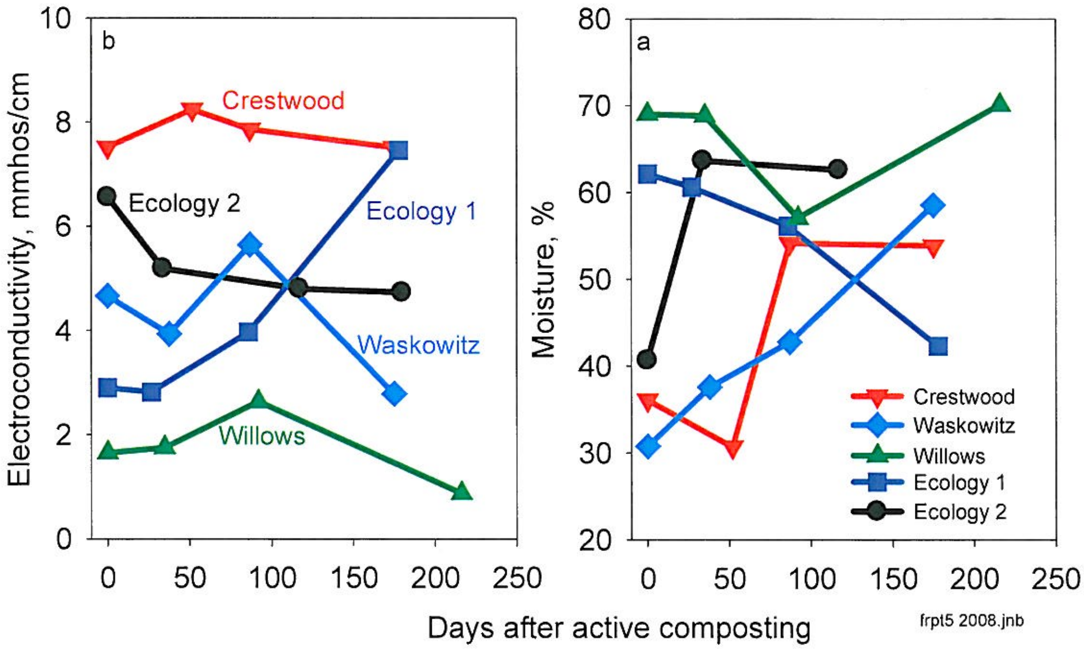

Figure 13. Compost moisture content (a) and electro conductivity (b) values during the stabilization phase of composting.

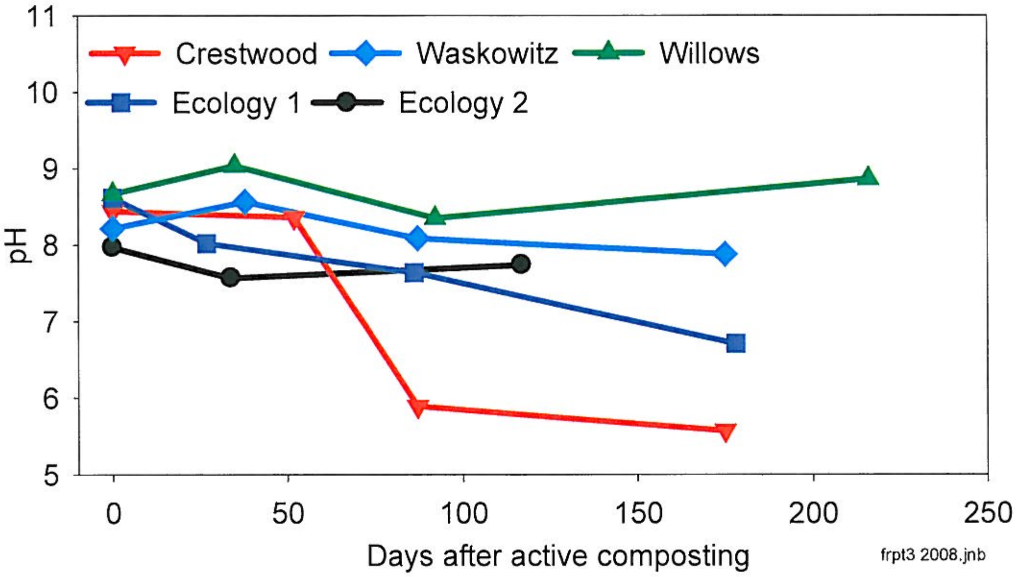

Figure 14. Compost pH during compost stabilization phase.

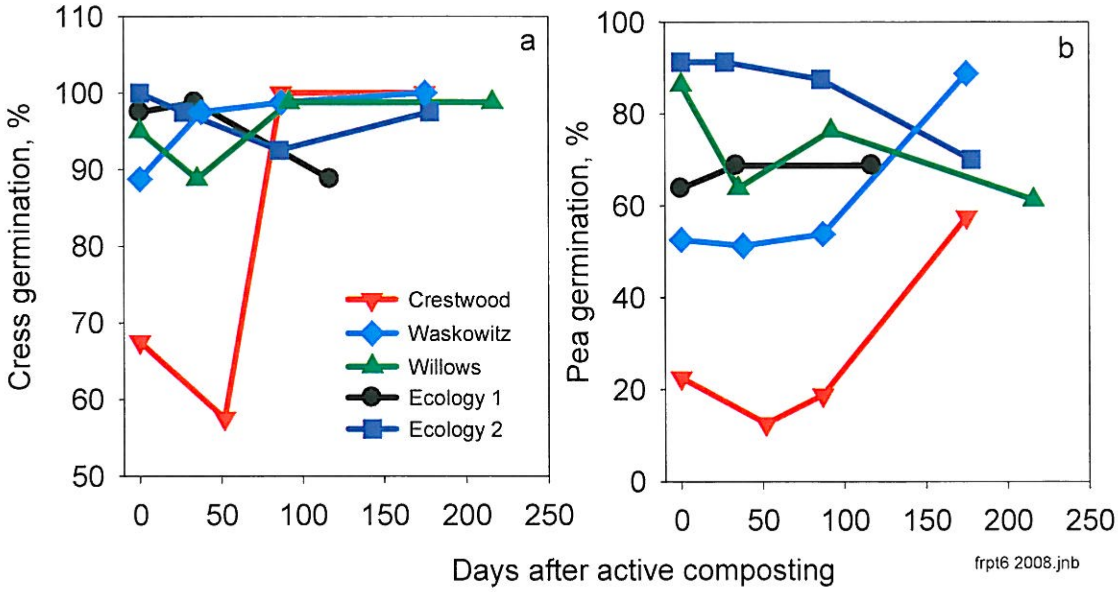

Figure 15. Cress and pea germination during the stabilization phase of composting.

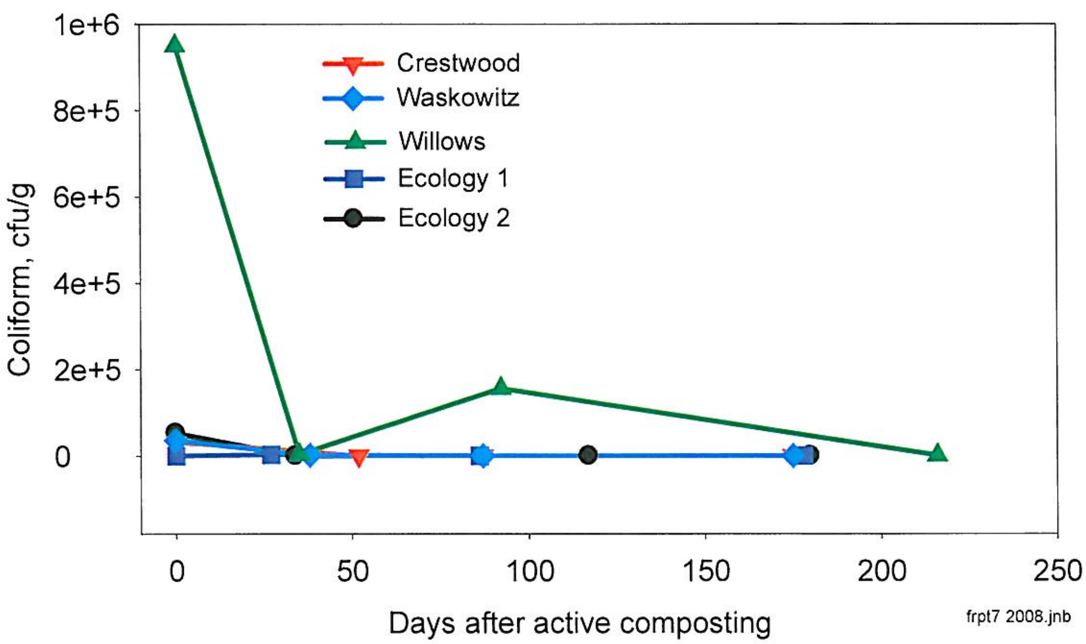

Figure 16. Compost total Coliform counts the stabilization phase of composting.

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Appendix 1. Crestwood Elementary active phase of composting temperatures, food weights and volumes

Date	Compost Age (days)	Temperature (F^0)	Food Added (lbs)	Food Added (gals)
24-Jan-07	1	82	8.0	2.0
25-Jan-07	2	92	18.0	6.0
26-Jan-07	3	80	23.0	8.0
29-Jan-07	6	30	34.0	12.0
30-Jan-07	7	58	69.0	21.0
31-Jan-07	8	94	78.5	26.0
1-Feb-07	9	112	91.0	30.0
2-Feb-07	10	110	103.5	34.0
5-Feb-07	13	53	115.3	39.0
6-Feb-07	14	60	132.0	42.0
7-Feb-07	15	102	152.0	47.0
8-Feb-07	16	50	162.0	52.0
9-Feb-07	17	54	188.0	56.0
12-Feb-07	20	48	203.0	61.0
13-Feb-07	21	92	213.5	64.0
14-Feb-07	22	58	226.0	68.0
15-Feb-07	23	64	241.0	73.0
16-Feb-07	24	114	252.4	77.0
21-Feb-07	29	38	284.4	83.0
22-Feb-07	30	38	290.4	87.0
23-Feb-07	31	40	308.0	90.0
26-Feb-07	34	58	328.0	95.0
27-Feb-07	35	60	338.5	98.0
28-Feb-07	36	106	348.5	101.0
1-Mar-07	37	75	370.0	105.0
2-Mar-07	38	45	383.5	110.0
5-Mar-07	41	46	408.5	115.0
6-Mar-07	42	42	421.0	118.0
7-Mar-07	43	82	446.0	123.0
8-Mar-07	44	110	456.0	128.0
9-Mar-07	45	82	481.5	133.0
12-Mar-07	48	79	487.5	136.0
13-Mar-07	49	74	494.0	140.0
14-Mar-07	50	62	504.0	145.0
15-Mar-07	51	50	510.0	148.0
16-Mar-07	52	55	517.0	148.0

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Date	Compost Age (days)	Temperature (F^0)	Food Added (lbs)	Food Added (gals)
19-Mar-07	55	102	541.0	154.0
20-Mar-07	56	105	549.0	154.0
21-Mar-07	57	70	555.3	154.0
22-Mar-07	58	96	568.3	158.0
23-Mar-07	59	72	576.3	161.0
26-Mar-07	62	64	586.3	165.0
27-Mar-07	63	60	596.3	168.0
28-Mar-07	64	60	603.8	172.0
29-Mar-07	65	61	613.8	175.0
30-Mar-07	66	60	626.3	180.0
2-Apr-07	69	58	636.3	183.0
3-Apr-07	70	63	643.3	186.0
4-Apr-07	71	.	660.8	189.0
5-Apr-07	72	87	683.3	193.0
6-Apr-07	73	92	709.3	198.0
16-Apr-07	83	45	716.3	203.0
17-Apr-07	84	40	725.8	206.0
18-Apr-07	85	51	742.3	211.0
19-Apr-07	86	42	747.8	213.0
20-Apr-07	87	56	778.8	216.5
23-Apr-07	90	80	784.8	218.5
24-Apr-07	91	104	792.3	221.5
25-Apr-07	92	80	809.8	224.5
26-Apr-07	93	101	809.8	230.5
27-Apr-07	94	93	819.8	232.5
30-Apr-07	97	78	829.8	235.5
1-May-07	98	70	849.8	241.5
2-May-07	99	82	865.8	246.5
3-May-07	100	92	883.3	250.5
4-May-07	101	100	915.3	256.5
7-May-07	104	80	937.8	261.5
8-May-07	105	104	953.8	267.5
9-May-07	106	90	961.8	269.5
10-May-07	107	92	974.3	272.5
11-May-07	108	88	1012.3	278.5
14-May-07	111	72	1024.8	280.5
15-May-07	112	86	1039.8	283.5
17-May-07	114	90	1065.8	289.5
18-May-07	115	113	1091.3	297.5
21-May-07	118	49	1096.3	305.5

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Date	Compost Age (days)	Temperature (F^0)	Food Added (lbs)	Food Added (gals)
22-May-07	119	50	1106.3	308.5
23-May-07	120	63	1115.8	312.5
24-May-07	121	65	1133.3	317.5
25-May-07	122	118	1143.3	321.5
29-May-07	126	90	1155.8	326.5
30-May-07	127	88	1171.8	330.5
31-May-07	128	62	1190.8	334.5
1-Jun-07	129	78	1215.8	338.5
2-Jun-07	130	108	1220.8	341.5
3-Jun-07	131	88	1229.8	344.5
4-Jun-07	132	63	1242.3	348.5
5-Jun-07	133	68	1254.3	351.5
11-Jun-07	139	80	1271.8	354.5
12-Jun-07	140	100	1284.8	358.5
13-Jun-07	141	90	1302.3	363.5
19-Jun-07	147	73.3		

Appendix 2. Department of Ecology active phase of composting temperatures, food weights and volumes

Date	Compost Age (days)	Temperature (F^0)	Food Added (lbs)	Food Added (gals)
12-Dec-06	1		128.2	30
13-Dec-06	2		261.6	60
14-Dec-06	3	80	394	90
15-Dec-06	4	80	523.6	110
18-Dec-06	7	118	523.6	110
19-Dec-06	8	120	698.2	150
20-Dec-06	9	134	873	185
21-Dec-06	10	142	961.6	215
22-Dec-06	11	140	1079.8	245
26-Dec-06	15	134	1182.2	265
27-Dec-06	16	136	1273.8	280
28-Dec-06	17	142	1375.8	295
29-Dec-06	18	136	1462.4	330
2-Jan-07	22	134	1564.6	350
3-Jan-07	23	136	1716.4	380
4-Jan-07	24	133	1857	415
5-Jan-07	25	138	1983.4	440
8-Jan-07	28	134	2096.6	460
9-Jan-07	29	142	2199	500
10-Jan-07	30	140	2291.6	540
11-Jan-07	31	140	2440.2	585
12-Jan-07	32	118	2568	620
15-Jan-07	35	115		
16-Jan-07	36	115		
17-Jan-07	37	115		
18-Jan-07	38	124		
19-Jan-07	39	134		
22-Jan-07	42	132		
23-Jan-07	43	132		
24-Jan-07	44	132		
25-Jan-07	45	134		
26-Jan-07	46	134		
29-Jan-07	49	130		
30-Jan-07	50	130		
31-Jan-07	51	134		
1-Feb-07	52	134		
2-Feb-07	53	134		
5-Feb-07	56	126		
6-Feb-07	57	100		

Appendix 2. Department of Ecology active phase of composting temperatures, food weights and volumes

Date	Compost Age (days)	Temperature (F^0)	Food Added (lbs)	Food Added (gals)
7-Feb-07	58	100		
8-Feb-07	59	100		
9-Feb-07	60	115		
10-Feb-07	61	100		
12-Feb-07	63	120		
13-Feb-07	64	120		

Appendix 3. Willows Lodge active phase of composting temperatures, food weights and volumes

Date	Compost Age (days)	Temperature (F^0)	Food Added (lbs)	Food Added (gals)
17-Jan-07	1		89	25
24-Jan-07	8	82	195.8	55
26-Jan-07	10	95	302.6	85
31-Jan-07	15		516.2	145
5-Feb-07	20		569.6	160
6-Feb-07	21	60	623	175
6-Feb-07	21	60	676.4	190
7-Feb-07	22	62	676.4	190
8-Feb-07	23	82	729.8	205
9-Feb-07	24		729.8	205
13-Feb-07	28	90	836.6	235
16-Feb-07	31	88	943.4	265
16-Feb-07	31	88	1050.2	295
16-Feb-07	31	88	1157	325
21-Feb-07	36	95	1263.8	355
23-Feb-07	38	100	1406.2	395
27-Feb-07	42	98	1584.2	445
2-Mar-07	45	92	1673.2	470
6-Mar-07	49	70	1780	500
8-Mar-07	51	70	1780	500
9-Mar-07	52	84	1869	525
13-Mar-07	56	91	2011.4	565
14-Mar-07	57	91	2100.4	590
16-Mar-07	59	100	2242.8	630
19-Mar-07	62	100	2314	650
21-Mar-07	64		2314	650
22-Mar-07	65	90	2420.8	680
23-Mar-07	66		2420.8	680
26-Mar-07	69	90	2527.6	710
29-Mar-07	72	98	2634.4	740
2-Apr-07	76	95	2634.4	740
5-Apr-07	79	95	2634.4	740
9-Apr-07	83	95	2634.4	740
12-Apr-07	86		2634.4	740
16-Apr-07	90	95	2634.4	740
19-Apr-07	93		2634.4	740
23-Apr-07	97		2634.4	740
26-Apr-07	100	95	2634.4	740
30-Apr-07	104		2634.4	740
3-May-07	107		2634.4	740

Appendix 3. Willows Lodge active phase of composting temperatures, food weights and volumes

Date	Compost Age (days)	Temperature (F^{0})	Food Added (lbs)	Food Added (gals)
3-May-07	107		2634.4	740
7-May-07	111	100	2634.4	740
9-May-07	113		2634.4	740
14-May-07	118	110	2634.4	740
29-May-07	133	.	2634.4	740

Appendix 4. Waskowitz Outdoor School active phase of composting temperatures, food weights and volumes

Date	Compost Age (days)	Temperature (F^0)	Food Added (lbs)	Food Added (gals)
26-Oct-06	1	55	7	2
27-Nov-06	32	55	25	9
4-Dec-06	39	55	50	14
7-Dec-06	42	55	71	20
12-Dec-06	47	55	97	26.5
8-Jan-07	74	55	102	27.5
16-Jan-07	82	55	104	28.5
22-Jan-07	88	55	108	31
26-Jan-07	92	55	120	35
29-Jan-07	95	55	138	40
2-Feb-07	99	55	147	42.5
5-Feb-07	102	55	162	47.5
9-Feb-07	106	55	167	49.5
12-Feb-07	109	55	172	51.5
23-Feb-07	120	55	177	54.5
26-Feb-07	123	55	177	54.5
27-Feb-07	124	55	177	54.5
28-Feb-07	125	55	177	54.5
1-Mar-07	126	55	185	56.5
2-Mar-07	127	55	194	59.5
4-Mar-07	129	55	226	70.5
7-Mar-07	132	55	291	88.5
9-Mar-07	134	55	341	100.5
12-Mar-07	137	55	365	107.5
13-Mar-07	138	55	384	117.5
14-Mar-07	139	55	451	131.5
15-Mar-07	140	55	469	146.5
16-Mar-07	141	55	472	147.5
17-Mar-07	142	55	472	147.5
20-Mar-07	145	43	492	157.5
21-Mar-07	146	48	514	168.5
23-Mar-07	148		569	172
27-Mar-07	152	60	619	183
28-Mar-07	153	55	665	196
29-Mar-07	154	60	703	207
30-Mar-07	155		724	217
26-Apr-07	182	136	746	223
27-Apr-07	183	138	770	230

Appendix 4. Waskowitz Outdoor School active phase of composting temperatures, food weights and volumes

Date	Compost Age (days)	Temperature (F^0)	Food Added (lbs)	Food Added (gals)
28-Apr-07	184	138	790	235
1-May-07	187	120	824	245
2-May-07	188	145	862	254
3-May-07	189	125	899	267
4-May-07	190	120	910	273
7-May-07	193	70	951	283
8-May-07	194	102	971	290
9-May-07	195	120	1012	313
10-May-07	196	138	1050	328
11-May-07	197	159	1067	331.5
14-May-07	200	80	1112	341.5
15-May-07	201	110	1139	351.5
16-May-07	202	130	1175	365.5
17-May-07	203	142	1214	378.5
18-May-07	204	122	1229	386.5
21-May-07	207	80	1269	396.5
22-May-07	208	120	1296	401.5
23-May-07	209		1336	412.5
24-May-07	210	60	1361	419.5
29-May-07	215	65	1393	427
30-May-07	216	95	1418	436
1-Jun-07	218	.	1458	448

Appendix 4. Washington State University Department of Ecology active phase of composting temperatures, food weights and volumes

Date	Compost Age (days)	Temperature (F^0)	Food Added (lbs)	Food Added (gals)
1-Jun-07	1		124.4	35
2-Jun-07	2		207	55
5-Jun-07	5	122	333.2	90
6-Jun-07	6	124	483.4	145
7-Jun-07	7	136	607	180
8-Jun-07	8	140	732.4	215
11-Jun-07	11	134	850.8	250
12-Jun-07	12	140	976.2	285
13-Jun-07	13	140	1105	325
14-Jun-07	14	144	1220.6	355
15-Jun-07	15	142	1345.4	390
16-Jun-07	16	144	1454	415
18-Jun-07	18	146	1454	415
19-Jun-07	19	142	1593.4	455
20-Jun-07	20	142	1734.4	500
21-Jun-07	21	144	1871	540
22-Jun-07	22	142	1994	575
23-Jun-07	23	144	2106	605
25-Jun-07	25	140	2106	605
26-Jun-07	26	146	2255.2	655
27-Jun-07	27	134	2384.8	695
28-Jun-07	28	142	2501.6	730
29-Jun-07	29	144	2568.8	750
2-Jul-07	32	132	2679.8	780
3-Jul-07	33	136	2816	825
5-Jul-07	35	136	2988.2	885
6-Jul-07	36	140	3113.8	925
9-Jul-07	39	140	3221	955
10-Jul-07	40	133	3324.2	984
11-Jul-07	41	146	3467.6	1029
12-Jul-07	42	142	3590.4	1064
13-Jul-07	43	140		
14-Jul-07	44	138		
16-Jul-07	46	140		
17-Jul-07	47	136		
18-Jul-07	48	142		
19-Jul-07	49	140		
20-Jul-07	50	144		
23-Jul-07	53	140		

Appendix 4. Washington State University Department of Ecology active phase of composting temperatures, food weights and volumes

Date	Compost Age (days)	Temperature (F^0)	Food Added (lbs)	Food Added (gals)
24-Jul-07	54	140		
25-Jul-07	55	142		
26-Jul-07	56	142		
27-Jul-07	57	142		
30-Jul-07	60	117		
31-Jul-07	61	134		
1-Aug-07	62	146		
2-Aug-07	63	144		
3-Aug-07	64	146		
6-Aug-07	67	120		
7-Aug-07	68	126		
8-Aug-07	69	140		
9-Aug-07	70	130		
10-Aug-07	71	126		

Appendix 5. Earth Tub™ Supplemental Operating Instructions

Supplement to Earth Tub™ Operating Instructions

Adapted from Karin Grobe Santa Cruse County, Public Works.

Note: these instructions are not intended to stand alone, but are a supplement to the Operating Instructions and the Troubleshooting guide included in the Earth Tub™ Operations and Maintenance Manual prepared by Green Mountain Technologies They are suggestion that can lead to successful operation of your Earth Tub™.

Starting a new tub

Put 6 cubic feet of large bark chips (about 2 inch diameter, available from garden centers) on the floor of the tub. Make sure the metal grate is well-covered. These large chips keep the small particles from falling through the metal grate.

Fill the tub about 1/2 full with dry sawdust/wood shavings mix. Distribute it evenly around the tub. This material absorbs the moisture from the food scraps. It also provides aeration spaces.

Adding food scraps

It is possible to add as much as 1000 pounds of food scraps in one day to a new tub that is half full of sawdust. When the tub has been going for a while, there will be less 'head room' and scraps must be added slower. Be sure to add sawdust or bread to balance the moisture. Distribute evenly over the surface of the tub, either by moving the opening port around the tub or by pushing the material across the tub with a gardening implement. The auger is meant to mix materials vertically, not horizontally.

Acceptable materials for composting

- Vegetables and fruits—large items like pumpkins and watermelons must be cut up. Do not add cardoon, a vegetable that is like a 1.5 foot long stick, as it could potentially overload the auger.

- Bread—OK to leave paper wrappers on, whole uncut loaves are fine. Bread is useful for balancing the moisture levels of vegetables.

- Salad mix—must remove plastic bags.

- Coffee grounds and filters, tea bags.

- Meat, cheese, etc, up to 10 percent of tub by weight. Holiday dinner scraps are no problem.

- Garden debris can be added if it is chopped small enough so it won't wrap around the auger.

Adding sawdust

Appendix 5. Earth Tub™ Supplemental Operating Instructions

You will need to add more sawdust periodically as the compost mixture gets too moist. Compost moisture can also be adjusted by adding bread, but some sawdust will be needed to keep the compost texture somewhat crumbly. If the compost moisture level is good but the structure is like clay, sawdust is needed for aeration. Also, if the compost smells like ammonia, more sawdust is needed to balance the high nitrogen levels in the food scraps.

Mixing with the auger

Move lid only when auger is turning. Trying to move the lid when the auger is not running may damage auger. Ideally, lid should make one revolution every 5 minutes. Remember that the auger is meant to mix materials vertically, not horizontally. Turning the lid this slowly allows maximum mixing of the material. Turning the lid rapidly also accomplishes mixing, but some of the energy you use is wasted. To thoroughly mix the material after adding a large volume of food scraps or sawdust, it may be necessary to make up to five revolutions. It is easier to turn the lid counterclockwise, but the electric cord to the auger eventually gets twisted. When it does, turn off the auger, open the little box and unplug the auger and untwist the cord. (This should be done each day.) Alternatively, turn the lid equally in each direction.

It is best to rotate the tub with the auger near the center of the tub first, then work the auger gradually out to mix the material further from the center. This makes it easier to turn the tubs, and there is less load on the auger.

Always auger after adding food scraps. The goal is to cover the food scraps, so they can start composting and they won't attract flies.

Emptying the tub

When you have added 2000-4500 pounds of food scraps to the tub, stop adding material and let the compost 'cook' for about 2 weeks. Continue to scrape the sides weekly to mix in the outer material. To remove the compost, spread tarps below the side tub doors and run the augers. Empty the tarps into a 4x4 wood bin. You will have to use a bucket or a shovel to remove material that is not pushed out by the auger. Some of the material that has not been reached by the auger will not be composted. Put it into the other tub.
Always clean your tub completely to avoid drainage problems. Always empty the tub out completely to check drainage under the aeration floor. The manufacturer recommends emptying the tubs out completely every six months. Between times, about 1/10th of the material in the tub should be left as a starter for the next batch of compost. Compost should be allowed to 'cure' for several months before it is used on gardens.

Record sheet

Note materials added, recording weight. Noting volume is optional, but is useful for figuring out savings on garbage bill. Note number of 5-gallon buckets of sawdust added. If water is added, estimate number of gallons by timing how long it takes to fill up a 5-gallon bucket, and squirting compost for timed intervals. As noted at the bottom of the record sheet, we have calculated that it takes about 40 seconds to fill a 5-gallon bucket if the water is turned on hard.

Temperatures
Optimum temperatures are from 131 to 140 degrees F. It is important that temperatures reach 131 or higher and stay there for at least three days during the 'cooking' phase, after all food scraps have been added to the tubs. This ensures pathogen destruction. If temperatures are running below 131 degrees F, close the ball valve on the aeration system. If temperatures do not increase, you can shut off the blower.

Moisture level
The compost should be as moist as a wrung out sponge. That is, if you squeeze a handful, your hand should be moist but not more than 1-5 drops of moisture should leak out. When starting a new tub, you can add moist scraps without adding sawdust (since the tub is already half-full of sawdust). Later on, if you add many wet scraps (lettuce, melons) you will need to add sawdust. Bread can help to balance wet scraps.

Odor
If compost smells strongly of ammonia, this indicates carbonaceous material is needed to balance nitrogen in the food scraps. Sawdust should be added.

Daily tasks
Check temperatures and moisture levels. Add produce and sawdust as appropriate. Mix both tubs with augers. You should unplug and untwist the auger electrical cord at the end of each day. Make notes on record sheet as appropriate.

Weekly tasks
Scrape sides of tub, so material between tub wall and auger gets mixed in. Check to make sure the biofilters are moist. If not, moisten them with a hose. You will need to stir the material with a shovel or pitchfork while moistening, and you may need to remove the material from the biofilter and add it in layers wetting each layer as you go.

Check hoses to make sure they are flowing and not plugged. If they get plugged, they must be disconnected and cleared out. You can try to clear them with a length of wire or connect them to the fresh water hose and blast them out.

Check sanitation around tubs and hose down/scrub with broom and bleach solution as needed. Clean tops of tubs as needed.

Listen for blower. It should always be on. When the blowers get wet, they often stop working, but they usually recover when they dry. Also, the GMT manual says you can push the black rubber knob that is visible through the air intake hole to free the blower wheel if it is stuck

Appendix 5. Earth Tub™ Supplemental Operating Instructions

Monthly tasks
Grease auger

Tasks for when tub is empty
Remove metal aeration floor and clear any small particles out of drainage and aeration system. Clean or replace drainage hoses as necessary for good moisture flow.