REFUSE AND REFUSE-SLUDGE COMPOSTING

By John S. Wiley*

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The composting of municipal solid wastes has been shown to be a practical sanitary method of treatment in Europe. The compost produced is sold as a low-cost soil builder and serves to make this treatment process competitive with other methods of solid waste disposal. The use of compost has proved beneficial in nearly all phases of agronomy, improving physical fertility and yield of cultivated soils and permitting land rebuilding or reclamation. European composting is conducted in the manner of sewage treatment in the U. S., generally in publicly-owned plants and with government assistance both in research and development and in plant construction in many instances (1, 2).

Developmental activities on composting are not as advanced in the United States as in Europe, and all plants have been built by private concerns, usually with profit-making as a primary motivation. The author advocates: development and testing of improved methods of waste collection and treatment; comprehensive planning of the over-all waste-disposal system; sound engineering plans for the specific waste-treatment process; and installation and operation of the plant to meet public works, sanitation, and health requirements (3). This paper presents some of the results of U. S. composting studies, and descriptions of two processes of composting widely used in Europe.

U. S. Composting Studies

Basic and applied research studies by the University of California (4) and Michigan State University (5), and by the Communicable Disease Center at Savannah (6) and at Chandler, Arizona (7) have shown that composting of organic wastes is technically feasible either in mechanical units or in windrows. These studies have dealt with the aerobic decomposition of organic wastes at between 40 and 70 per cent moisture content. Decomposition proceeds largely in the thermo-

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philic temperature range, above 113°F, generally reaching temperatures in excess of 140°F, when the wastes contain sufficient readily-decomposable matter. The principal decomposition products are humus or humus-forming substances, carbon dioxide, and water.

The CDC studies showed that 30 to 40 per cent decomposition of the volatile solids (organic matter) in sorted and ground refuse occurred in 6 to 11 days in laboratory mechanical units or in 29 to 43 days in windrows and bins (Table 1). The various constituent

Table 1

Summary of Weight Changes in Laboratory and Outdoor Composting of Refuse

Type of Composting:	Laboratory Mechanical Units (Savannah)			Outdoor Windrows and Bins (Chandler)		
Composting conditions:	Continuous mixing and aeration			Natural aeration; intermittent regrinding		
Mean composting time, days:	8.8			34.4		
Mean number of regrinds:	---			5		
Total number of: Units / Runs	32 units / 13 runs			4 windrows, 25 bins / 4 groups, 2 runs		
Constituent	Average Weight, pounds per unit		Change in Weight, %	Total Weight, pounds		Change in Weight, %
	Initial	Final		Initial	Final	
Total Wet Weight	40.47*	27.31	-32.5	71,080[x]	42,482	-40.2
Moisture	24.58*	15.85	-35.5	33,147[x]	14,336	-56.8
Total Solids	15.89	11.46	-27.9	37,933	28,146	-25.8
Ash	1.25	1.43	+14.4	12,511	12,586	+ 0.6
Volatile Solids	14.64	10.03	-31.5	25,422	15,560	-38.8
(1) Lipids	1.62	0.38	-76.5	2,500	590	-76.4
(2) Crude Fiber	5.66	5.26	- 7.1	14,148	8,888	-37.2
(3) Total Sugar	0.80	0.0008	-99.9	------	------	-----
(4) Starch	1.32	0.15	-88.6	------	------	-----
(5) Protein (6.25N)	1.29	1.26	- 2.4	1,353	1,131	-16.4
(6) Sum (1) to (5)	10.69	7.05	-34.1	18,001	10,609	-41.1
(7) V.S.-(6) (Undeter.)	3.95	2.98	-24.6	7,421	4,951	-33.1
Nitrogen (N)	0.207	0.202	- 2.4	216.5	181.0	-16.4
Carbon (C)	7.96	5.47	-31.3	14,235	9,024	-36.6
Ratio: C/N	38.5	27.1	-29.6	65.8	49.9	-24.2

*Includes initial moisture plus moisture added during composting runs.
[x]Does not include moisture added during composting runs.

weights were obtained from the initial and final wet weights and the analytical results (not shown). Raw materials consisted of well-sorted, ground refuse and water at Savannah, and grossly-sorted, ground refuse and water or raw primary sludge at Chandler. Table 1 shows that good decomposition of sugars, starch and lipids occurred. While some nitrogen was lost in outdoor composting, there was a negligible loss in the laboratory units. The volatile solids content of the end products was slightly more than half crude fiber in both cases. While the composts were subject to further decomposition of the more-resistant organics, they were sufficiently stable to remain aerobic without additional turning or aeration. The course of temperature and pH with time by the two methods is shown in Figure 1.

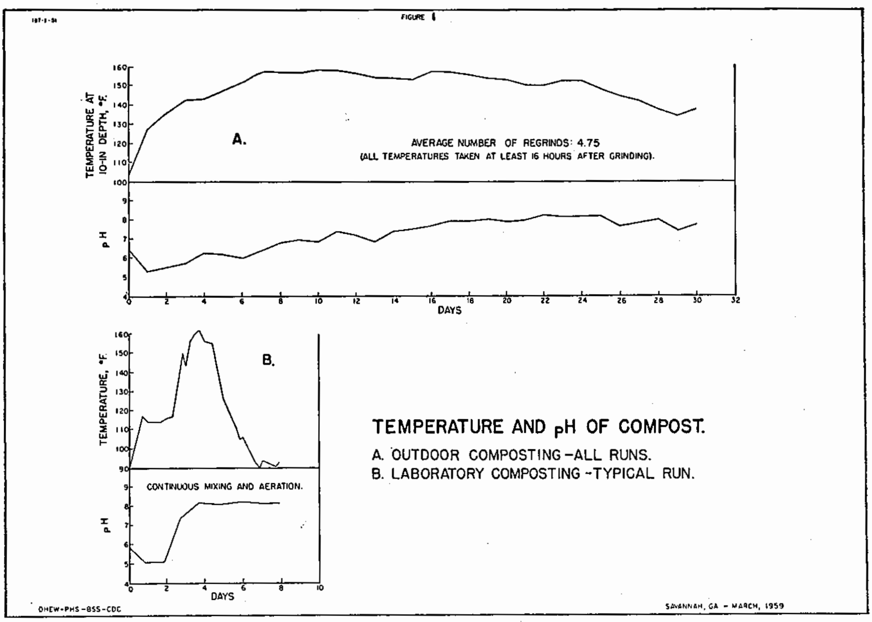

FIGURE 1.

The closed, insulated units at Savannah permitted running experiments in which stoichiometric balance could be obtained (Table 2). The composting materials were slowly stirred and aerated. Incoming airflows were metered, and measured portions of outlet air were sampled continuously for moisture and CO_2 and intermittently for O_2. Figure 2 shows temperature, CO_2 and H_2O discharged, O_2 used, and pH values with time in a typical laboratory composting run. Good correlations were found to exist semi-logarithmitically between temperature and (a) CO_2 produced, (b) H_2O produced and evaporated, and (c) O_2 consumed. Correlation coefficients averaged between 0.75 and 0.85 when the temperatures were plotted arithmetically and the lines of best fit were computed by the method of least squares (6).

TABLE 2
STOICHIOMETRIC BALANCE
AVERAGE VALUES FOR 32 DRUMS IN 13 RUNS
(POUNDS)

Constituent	Intake	Output
Volatile Solids	14.64	10.03
Ash	1.25	1.43
Total Solids	15.89	11.46
Moisture	24.58*	15.85
Total Composting Materials	40.47*	27.31
Oxygen Used	6.79	—
Water Evaporated	—	8.73
Water Produced	—	2.60
Carbon Dioxide Produced	—	8.52
Total	47.26	47.16
Respiratory Quotient	0.91	

* Includes moisture added during composting runs.

The respiratory quotient (vol. CO_2/vol. O_2) was of the order of about 0.9 (Table 2). These results agree remarkably well with those obtained by Schulze at Michigan State University (5).

Thermophilic aerobic composting should produce minimal health and nuisance hazards both during the composting process and regarding the end-product. Objectionable odors should not be produced, as in anaerobic decomposition, although some volatile constituents should be expected in the discharged air. The combined action of time-temperature (thermal kill) and antibiotic agents produced by the decomposing organisms is reported to cause pathogen destruction (8). Weed seeds, fly eggs and larvae, and plant pathogens are also similarly destroyed (8).

The highly satisfactory results of research on the technical feasibility of composting in the U.S. indicates the need for the next step: the construction and proving of full-scale composting plants.

EUROPEAN COMPOSTING

Perhaps the United States will now look to Europe where composting processes, together with specialized equipment, have been well demonstrated, not in one or two prototype installations but in dozens of active plants composting refuse and refuse-sewage sludge (1, 9). At least two European processes are believed by the author to be worthy of study for adaption to U. S. conditions: the Dano biostabilizer method and the rasping system with windrow composting.*

Dano Method: In approximately 30 installations in Europe, the Dano biostabilizer system provides refuse sorting, composting with continuous tumbling and aeration for about 3-5 days, and refinement and curing of the compost. Process steps are illustrated in Figure 3.

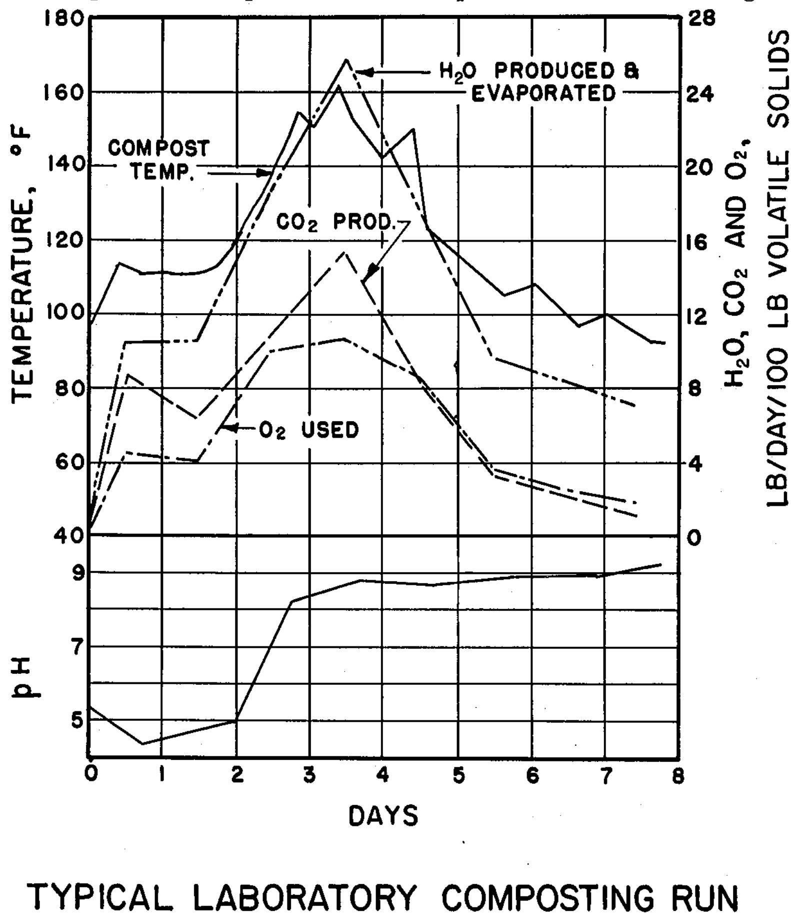

FIGURE 2.

* Reference in this paper to commercial equipment and processes is for identification purposes only and does not constitute endorsement by the Public Health Service.

THE DANO BIOSTABILIZER COMPOSTING PLANT AT SOEST-BAARN

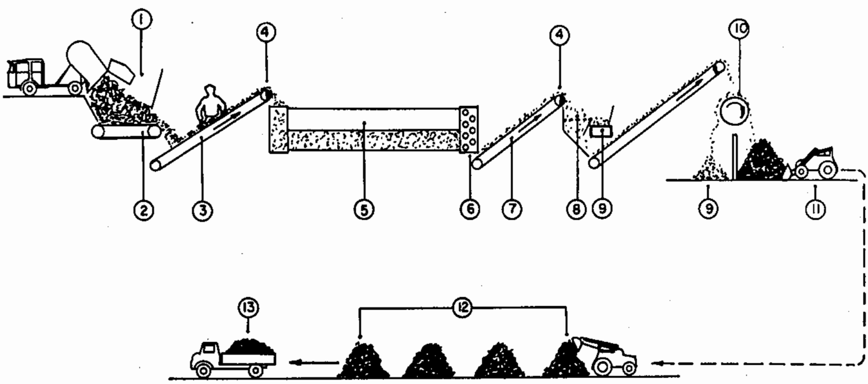

FIGURE 3.

The biostabilizer, designed to process unground refuse to which water, sludge, or nightsoil has been added, is a slowly rotating horizontal drum with positive aeration for the composting wastes. The latest European design incorporates wet scrubbers for odor control of the outlet air. The biostabilizer provides for aerobic thermophilic decomposition of the wastes by aeration, mixing, and gradual particle-size reduction caused by the tumbling-shearing action. The drum is at least 9 ft. in diameter and may be 50 to well over 100 ft. in length. It is generally operated at about ¾ rpm during the receiving period and ¼ rpm during the remaining time.

Refuse is sorted to remove salvable and unwanted items by hand and magnetic separation. In Europe the unground refuse is then charged directly into the drum inlet. The drum provides mixing for water, sludge, or other liquid wastes that are also added at the inlet end. At some installations, difficulty has been encountered in feeding large items indicating a need for preliminary grinding of part or all of the refuse, perhaps a necessity for U. S. refuse.

The matter of retention time is largely one of economics. Decomposition is much faster with continuous mixing, aeration, and grinding than under conditions of quiescence and natural ventilation. However, adequate stabilization of the compost for immediate general distribution would require a retention of more than five days. Retention of only one day, as at a few installations, merely provides a good start for the decomposition process and requires further active composting by another means. Depending on the character of the wastes and other factors, retention of 3 to 7 days in a biostabilizer may permit subsequent curing of the compost in undisturbed windrows or small piles without creating a nuisance or hazard to health.

Most Dano units have an integral screen section with coarse perforations (about 4 in. diameter) at the discharge end. Refinement of the compost may consist of finer screening and ballistic or gravity separation designed for removal of hazardous or unwanted materials such as glass, metals, cinders, and the like. Curing of compost is generally provided last, in windrows or small piles. Drying and bagging are usually not practiced, as the compost is generally sold in bulk at a price of only $1.45 to $4.40 per ton.

Rasping System: This system is named for the grinder, a "rasping machine," developed by the Dutch V.A.M. (Refuse Disposal Company) and made by Dorr-Oliver, N.V., Amsterdam (2). Figure 4 shows the

THE RASPING SYSTEM COMPOSTING PLANT AT DELFT

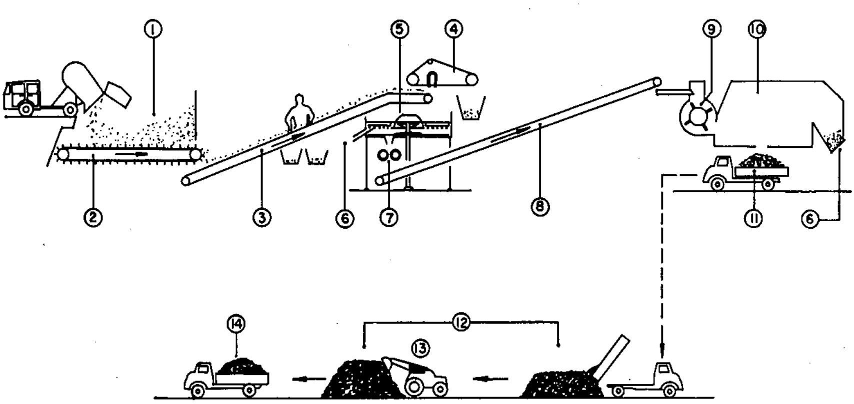

FIGURE 4.

steps in the process, which consists of refuse sorting, grinding, and refining, followed by windrow composting for 3 to 5 months.

As in the Dano system, hand and magnetic separation, with salvage, are practiced as the first step. The rasping machine is a large vertical drum with heavy hinged arms slowly rotating horizontally over alternate plates with pins and holes. The refuse is "rasped" until it falls through the perforations, usually 5/8 to 1½ in. in diameter. Ground refuse falls to a floor beneath where it is scraped to a discharge chute. A gate may be opened from without for the discharge of tailings, an operation required about once daily under European conditions. The rasping machine has a higher first cost but much lower maintenance cost and power requirement than the usual high-speed hammermills.

Rasping machines are generally followed by roller crushers to reduce the particle size of glass splinters, shards, or cinders. The raw ground refuse is then refined by means of a ballistic separator in which impellers on a high speed rotor fling the materials horizontally or at a slight upward angle. The unit provides both grinding and classifying with dense and resilient particles being separated from light and pliable materials.

Windrows in which the composting occurs are generally outdoors on an impervious surface and are usually 6 to 8 ft. high and 6 to 8 ft. wide at the base. The Dutch practice is to turn the windrowed material after 6 weeks and allow a total composting time of about 12 weeks. A front-end loader is normally used for both turning and loading compost. A shorter composting period may be scheduled when more frequent and vigorous turning and aeration are practiced.

Demand for compost usually exceeds the supply in Europe, even in the Netherlands where about one-fourth of all city refuse is composted and where also the greatest use is made of chemical fertilizers.

Refuse-Sludge Composting

Raw sewage solids enhance the composting of refuse, improving both the decomposition and the final compost. The raw sludge raises the nitrogen content of the refuse and adds in other ways to hasten composting. The final compost is improved in both structure and nutrient content. There are a number of examples in Europe of plants composting refuse with sludge, and several means have been developed in Germany for sludge thickening. Moisture must be added to most mixed refuse for optimum composting; and the cost of composting is little affected whether water, sludge, or other liquid wastes are used to supply the moisture. The composting of all refuse and sludge from the same contributory population, however, will require some thickening of the sludge to avoid excessive moisture in the mixture. Reports of two inexpensive means of concentrating either raw or digested sludges have been made recently (10, 11).

Waste treatment by composting of mixtures of refuse and sewage sludge may have economic advantages in the United States.

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DISCUSSION

By Frank L. Heany,* Member

Composting, at first glance, appears to be the most attractive means of disposal of municipal refuse. Advances in the technique now promise, at long last, the use of this method by some of the municipalities in the United States.

The other two generally accepted methods of disposal by sanitary land-fill and by incineration will continue to be competitive depending upon the particular conditions to be met at the municipality under consideration.

In many cases, annual costs for composting, as well as the valuable end product, should provide favorable competition with incineration. Sanitary Land-Fill, in most cases, will be cheaper than either, but may not be feasible due to shortage of available acreage required for land-fill operations. The open dump and the covered dump with open raw face are being outlawed in more and more sections of the country.

The effects of improper disposal are well-known to us in the Greater Boston Area. Vigorous steps are now being taken by the Massachusetts Department of Public Health to correct these conditions, now that the Legislature has finally given them the power to act. The smells, the persistent fires with their smudge filtering through residential areas, the rats, the roaches and the flies are now within hope of being eliminated.

The sanitary engineer's concern with this problem is based upon effects on public health and the noxious effects on the environment involved in the disposal of rubbish, garbage from municipal sources, as well as refuse from industries.

We might consider the problem limited to the refuse collected by the municipalities. This is homogeneous to the extent that it is restricted generally by ordnance to ordinary residential rubbish and garbage. Even so, cans, wire, and other metal objects many times amount to more than 15 percent by volume of this refuse. These cans are not washed clean but contain residue of food-stuffs. If not passed through an incinerator, this material must be buried with two feet of earth cover to prevent breeding of rats and vermin.

We cannot close our eyes to the refuse being collected by private

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agencies which now finds its way to the Town Dump. Stumps from the hurricanes and Dutch Elm ravages, upholstered furniture, refrigerators, etc.—these items are not suitable for incineration or for composting. It thus appears that a limited extent of sanitary land-fill should be a part of most refuse disposal projects.

The U.S.P.H.S. has sponsored field demonstrations locally to prove the ramp type of sanitary land-fill to be feasible with purchase, if necessary, of suitable cover material hauled to and stockpiled at the fill area. This method can be used, if land is available, even adjacent to built-up residential sections.

A good deal of the present commotion is caused by the mushrooming of residential single family development in practically all communities. In many cases there are no longer any remote locations for the old-fashioned dump within reasonable distance on all-weather-type roads.

The engineering approach is just as necessary for a good solution of municipal refuse disposal problems as it is for sewage disposal questions. The funds involved are important. It is fairly common for a city of 30,000 to spend $150,000 per year for collection and disposal of domestic refuse. Air-pollution, possible spread of disease, and destruction of property values through improper handling of this problem are factors requiring an increase in the demand by public agencies for serious engineering study of this matter.

DISCUSSION

By John A. Bellizia

In Massachusetts the problems of garbage and rubbish disposal are becoming more acute each year. The Department of Public Health is receiving an ever increasing number of complaints regarding insanitary refuse disposal practices and resultant nuisance conditions. As the population migrates from the cities to the suburbs, new dwellings are being constructed in rural areas containing farms, including hog farms. These garbage disposal facilities, formerly located in isolated areas, were operated without complaint for many years. The new suburbanites who find their houses located beside a piggery are not reluctant to complain about the odors, flies and rats from the piggeries. As a result several communities have found it necessary to regulate piggeries out of existence. In a recent court case the Supreme Court of the Commonweath upheld the right of the board of health to prohibit the operation of a piggery in the town. Other "bedroom" communities are showing interest in similar prohibitory regulations.

The open face dump, which formerly was practically the only means of rubbish disposal utilized in the Commonwealth, is also being crowded out of existence. Rules and regulations of the Department of Public Health of the Commonwealth adopted in 1961 will eventually result in the absolute prohibition of burning of rubbish in open dumps in the Metropolitan area. Once burning is prohibited, the increase in the number of flies and rats breeding in the unburned rubbish will undoubtedly result in such a volume of complaints that the Department will find it necessary to prohibit the operation of the open dump. This can be done under Section 150A of Chapter 111 of the General Laws which provides that the Department may, after due notice and a public hearing, modify the assignment of an area for refuse disposal purposes upon determination that the dumping ground results in a nuisance and a danger to the public health. The Department has found it necessary to hold hearings in regard to the operation of open dumps in five communities in Massachusetts during the past year, and in every instance has recommended that the open face dump be abandoned and sanitary landfill installed. Other communities, where sanitary landfill is not practical, have installed incinerators with a resulting large increase in the tax load on their residents.

A single composting plant has been operated intermittently by a private concern in the Commonwealth. The plant has engaged in the composting of garbage rather than combined refuse. The end product is said to be readily salable. The plant is located in an isolated area but has been operated in a manner which would create objectionable conditions had there been industrial plants or residences nearby.

The Department is not entirely convinced of the practicability, at the present time from an economic standpoint, of the composting of either separate garbage or combined refuse. While it is doubtful that the Department would encourage the construction of a municipal composting plant, there is no doubt that such an installation would be approved on an experimental basis. At the present time, however, Massachusetts communities and industries seem reluctant to invest the necessary funds to construct such a plant.