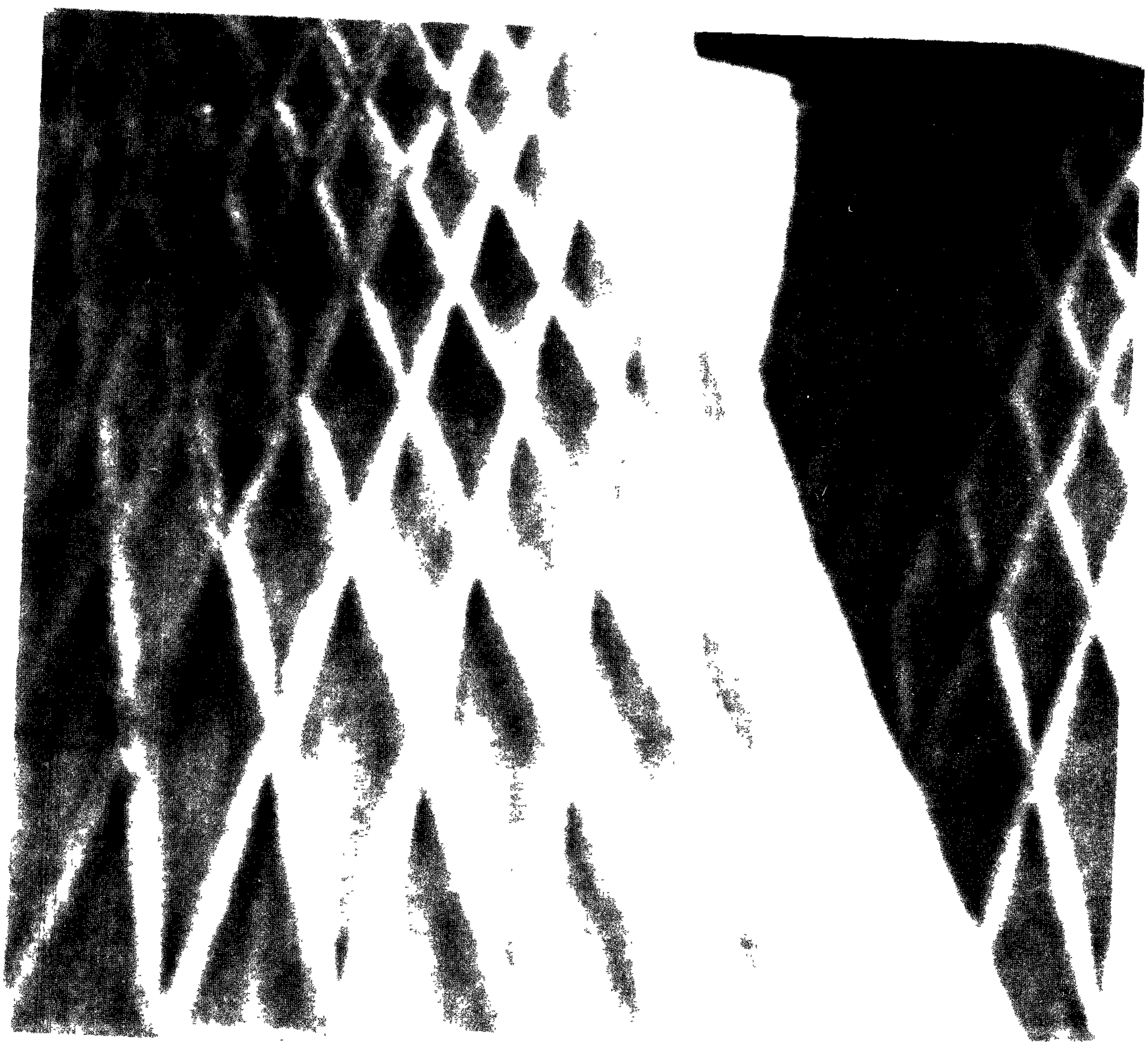
SW-2c

Solid Waste Management / *Composting*

European activity and American potential



Solid Waste Management / Composting
European activity and American potential

This report (SW-2c) was written for the Solid Wastes Program
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Foreword

Reports from Europe have suggested that composting and compost utilization have been more successful there than in the United States. A study was therefore made of the status of composting and compost utilization in Germany, Holland, and Switzerland, and the findings were related to the solid wastes problem in America.

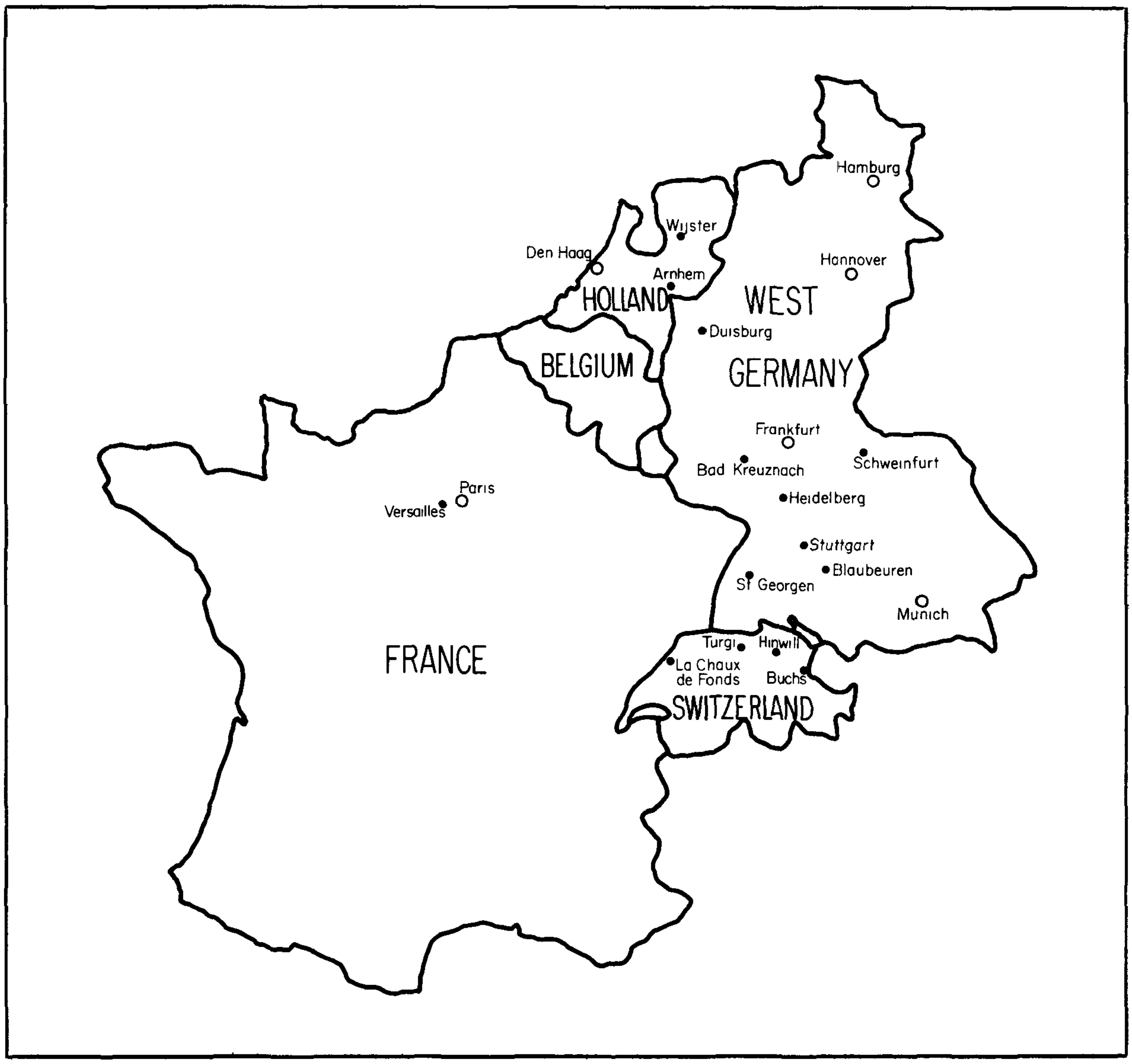
Nine compost plants are in operation in Germany, one-sixth of Holland's domestic refuse is made into compost, and Switzerland has an active composting program. Yet, in all three countries, composting is a very minor pathway for the disposal of solid wastes, and there are serious production costs and marketing problems. These countries make only as much compost as can be sold; excess refuse from the communities is burned or buried. Generally, compost can be sold only if it is well screened and of good appearance. The compost is used almost exclusively in luxury agriculture—bulb and flower growing, grapes for fine wine production, and gardens and parks. There is simply no market for the compost in basic agriculture.

This same approach to composting has also been attempted in the past in the United States. The results have been similar, though even less successful: The market (in luxury agriculture) has been smaller, and the cost of producing the compost has been greater.

There are possibilities, however, for a more satisfactory program of composting for solid waste disposal. Rough-quality compost, cheaply produced, without grinding or fine screening, has real potential for the reclamation of spoiled lands (as from mining), for the prevention of erosion, for reduction of the volume of material going into a landfill, and as a cover material for above-grade landfills. A further and even more favorable avenue of composting practice will be to consider land as an acceptor of compost rather than compost as a benefit to the land. Rough-quality compost might be applied at the maximum assimilable rate (perhaps 100 tons per acre-year) to a piece of land. The land would not be used for crop production, but neither would the land be irreparably changed, as with a landfill or dump. If or when the land becomes needed for subdivisions or agriculture, the compost application could be stopped and the land would recover.

This report fulfills U.S. Public Health Service Contract PH 86-67-13. It contains detailed findings of a European survey and proposals for future American research and practice.

—Richard D. Vaughan
Chief, Solid Wastes Program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Versailles
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St Georgen
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Hinwil
La Chaux
de Fonds
Buchs
SWITZERLAND

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Introduction

Solid waste management in Europe has long been lauded as a model of efficiency and appropriateness. The argument or explanation has been that, in densely populated Europe, one simply must be right about waste mangement—and the Germans, Swiss, Dutch, and other Europeans *are* right.

One of the foremost claims has been of the success of composting—and two examples are always cited to substantiate the claim. The first is that eight (recently nine) composting plants have begun operation in Germany since World War II, that not one has shut down, and that all are producing compost to capacity. The second is the success of composting manufacture and sale by the VAM (Vuilafvoer Maatschappij, or Waste Transporting Corp., Amsterdam and Wijster, Holland. That corporation makes 160,000 of the 200,000 tons of municipal compost produced in that country each year, and some eight cities and towns, including the capital of Den Haag (1 million inhabitants), deliver all their municipal waste to that organization.

These examples and others are correct, and do point up the success of these European composting activities. Nevertheless, even these successes are not unqualified (as will be discussed later), and their success cannot be transferred automatically and unequivocally to the American scene. Still, an indepth study of the situation in Europe may assist understanding what might be appropriate in the United States.

In 1964, G. J. Kupchick, under a World Health Organization Fellowship, undertook a comprehensive study of composting costs in Europe and Israel.* His analysis of 14 composting plants, serving a total population of over 3,136,000, indicated an average composting cost of $4.55 per short ton (2,000 pounds) of raw refuse received. Although the sale price of the completed compost averaged $2.73 per short ton, with a maximum price of $5.45 per short ton, it averaged only $0.90 income per ton of raw refuse received by the composting plant. (Salable compost weight was between 16 and 70 percent of the weight of the incoming raw refuse, the loss being due to removal of noncompostables, moisture loss, and the organic degradation loss that converts refuse to humus.) The net cost of composting (with allowance for iron, rag, and paper salvage, if conducted) amounted to $3.38 per short ton of raw refuse accepted.

It is not the purpose of the present report to further study the economics of composting. The fact that such substantial quantities of compost are produced and utilized in Europe and Israel makes it appropriate to study some of the factors related to compost use, and that is the major emphasis of this report.

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*Kupchick, G. J. Economics of composting municipal refuse in Europe and Israel, with special reference to possibilities in the U.S.A. *Bulletin of the World Health Organization,* 34(5): 798–809, May 1966.

Composting in Proper Perspective

For many years composting has been considered a "waste-utilization" activity, and therefore somehow "good." This is in comparison with landfilling, burial, and incineration, which have been thought of as "waste-disposal," and therefore not quite so "good." But today there are planned landfilling operations which are reclaiming land for future use, and there are a number of European incinerators which produce usable steam or electric power from burning municipal refuse. An appropriate starting point for more careful analysis of composting is a new and careful defining of solid waste management.

Man, especially the modern city man, produces large amounts of solid waste. If these wastes are discharged indiscriminately and without control, they degrade the environment in which man lives. To prevent or minimize degradation of the environment, man must "manage" his wastes. This management consists basically of performing five distinct unit operations: Collecting; transporting; storing; processing; discharging.

The first three operations are often repeated several times in various sequences. For instance, with domestic refuse the housewife collects and transports the waste from its point of production (kitchen sink or wastepaper basket) and stores it in the garbage can until it is picked up by the refuse collection agency. In turn, this agency transports and stores the material—in the truck or at an intermediate transfer point. The first three operations together—collecting, transporting, and storing—can be considered the first step in solid waste management.

"Processing" is the changing, modifying, or converting of a material. The change can be physical, chemical, or biochemical. In solid waste management practice only three basic procedures are presently available to process solid waste—incineration, composting, and burial.

It is easy to see how incineration and composting fit the definition of processing—of changing or modifying the product. Burial is also a processing operation, because the waste is compacted and incorporated into a physical part of the earth. Even in an open dump, where the waste is strewn over the land, the waste is, in an objectionable sense, processed or converted—into flies, rats, smoke, odor, and other nuisances. These undesirable products are the result of improper and uncontrolled processing.

"Salvaging," the removal of marketable materials from the total mass of the refuse, is sometimes practiced in solid waste management. The picking operation usually occurs during processing of the main body of waste. In truth, however, salvage is really a part of the discharge operation.

The last unit operation in solid waste management is "discharge." It has usually been called "utilization" or "disposal," but, as pointed out

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earlier, this unfairly lauds composting and deprecates landfilling or incineration. The more meaningful impression is conveyed by calling this last step "discharge—into the environment." The flue gas from a refuse incinerator is a discharge into the environment. The compost that the farmer or city park department spreads on the field or playground is also such a discharge into the environment. And in the burial of wastes the "discharge" is the *total landfill site,* not the material within the landfill. At some future date the landfill will be completed, and the site will be discharged into the environment, becoming available for some other use. Whether the use is an asset or a liability to the community depends upon how the refuse was originally "processed" into the site.

Similarly, the salvage operation returns the salvaged material into reuse channels, and thus is also a discharge into the environment.

This concept of solid waste management attributes no special merit to one system of processing over another. Composting is basically no different from other processing techniques. It is preferred when it is the most economical system, or when the "discharge into the environment" via composting is less detrimental than the discharge from other processing methods, and if society is willing to pay the additional price for the lesser insult to the environment.

Survey of 14 European Composting Plants

This study of European composting activity was primarily concerned with utilization of compost after manufacture. In the pursuit of this goal, 14 European composting plants were visited. In addition to learning how these plants dispose of their compost, information was obtained on their composting equipment, facilities, and procedures. A brief description of the operation of the plants is interesting in itself, and adds to the understanding of composting as a method of solid waste management.

The composting plants that were visited are indicated in figure 1.

Composting is more applicable to a city's domestic refuse than to commercial or industrial refuse, and composting is not generally appropriate to debris from construction and demolition. Thus, most European composting plants accept only domestic refuse and have alternate or supplementary facilities for handling the noncompostable parts of commercial and industrial refuse. Even with domestic refuse, a considerable percentage (15 to 30 percent by weight) is not compostable and must be removed before the compost can be sold or used. The details of this process and others are best explained as they apply to individual plants.

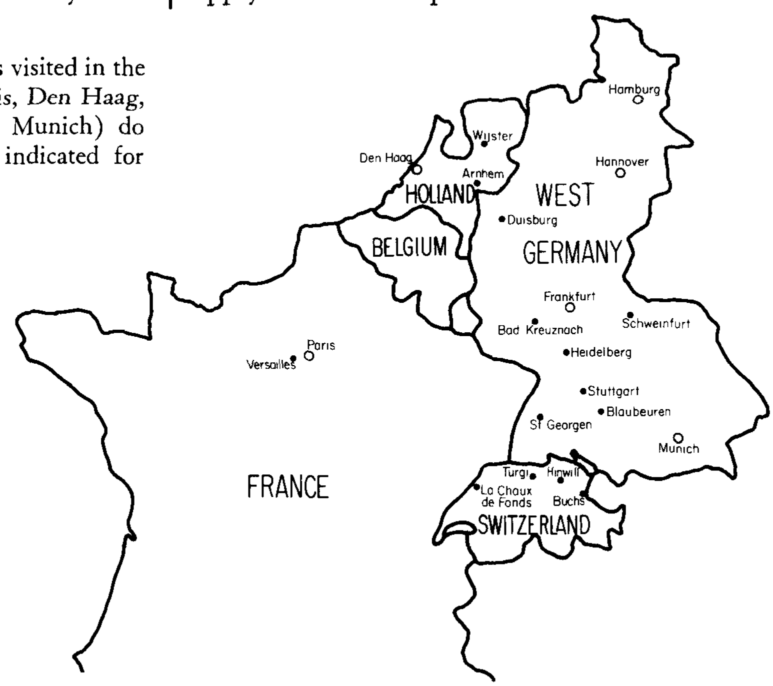


FIGURE 1. Locations of composting plants visited in the course of this study. Major cities (Paris, Den Haag, Hamburg, Hannover, Frankfurt, and Munich) do not have composting plants but are indicated for orientation purposes.

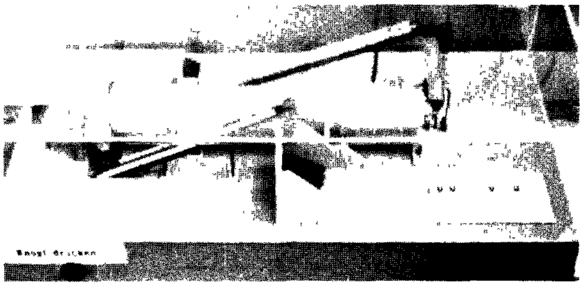


FIGURE 2. Model of Dano composting drum at Bad Kreuznach (and also at Duisburg and Hinwill).

FIGURE 3. Exterior of compost building. Bales of compressed tin cans are lined against the wall at the left.

Bad Kreuznach, Germany

Population served, 45,000
Type of plant, Dano

One of the most successful composting operations in Europe is at Bad Kreuznach. This city, near the center of the Riesling wine area, is on the Nahe River, a tributary of the Rhine. Much of the vineyard acreage of the area is on steep hillsides, where added organic matter is needed to prevent excessive soil erosion. Manures and similar organic materials have been in short supply in the Bad Kreuznach area. Thus, in 1958 the BVB (Bodenverbesserungverband, or Soil Improvement Cooperative) of the local grape farmers (under the leadership of its president, Mr. O. Andres) entered an agreement with the city and the state. The compost plant, belonging to the farmer cooperative, was built on city land adjacent to the sewage treatment plant. The city's public works department collects and hauls domestic refuse to the compost plant, where it is discharged into the composting drum. The city pays DM 80,000 (about $20,000) per year for this dumping privilege, which is less than the cost of hauling the waste to a more distant landfill and burying it. (The landfill is used for commercial and industrial wastes, except winery wastes.) Sewage sludge from the adjacent plant can be and has been incorporated into the compost, but at present it is hauled away as liquid sludge by the farmers and used in that form.

The unground, raw domestic refuse brought to the composting plant, along with raw winery wastes in winter (the lees, or skins, seeds, and stems), is put into the Dano drum. Residence time there is 3 to 4 days. The partially composted material is then removed from the drum. Iron is removed with a magnet, and the compost is sieved. The compost is then piled into windrows for curing and storage until purchased by the farmer—in the fall of the year. Thus, some compost is stored 9 or 10 months. The noncompostable material—"scalpings" from the sieve—are used for fill material at the compost site. (The plant was located on low-lying ground, and the approximately 10-acre compost storage site has been raised about 6 feet in 10 years of operation.)

About 8,000 cubic meters (10,500 cubic yards) of compost are manufactured each year from the incoming 25,000 cubic meters (33,000 cubic yards) of raw domestic refuse. The compost is sold to the Cooperative members for DM 10 per cubic meter ($1.90 per cubic yard), f.o.b. the compost plant. This revenue of DM 80,000 ($20,000), plus the city's payment of DM 80,000 ($20,000), just equals the cost of making the compost (labor, maintenance, and equipment amortization).

The state's contribution to this venture has been to furnish a part of the capital and to pay the salary of a research scientist attached to the operation. These research scientists (formerly Dr. H. J. Banse, now Dr. I. Bosse) have done research on the composting operation itself and on compost utilization. The compost utilization research has consisted of measuring runoff wa-

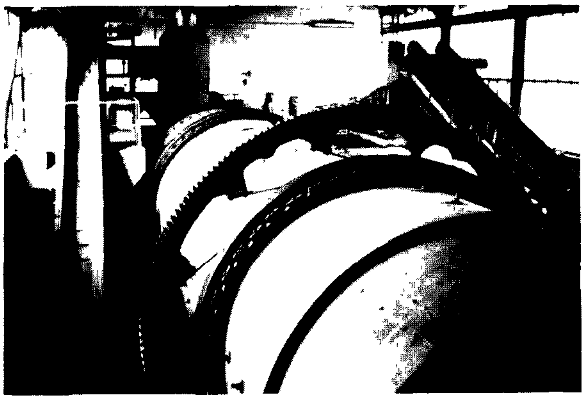


FIGURE 4. Interior view of building.

FIGURE 5. Curing yard (on a frosty morning).

ter and runoff soil from some steep experimental plots. (This is discussed on page 28 with the German research.) The success of the Bad Kreuznach composting operation is due to all the above factors—economy to the city, state support, and, most important, a good market for the compost. All factors may well be required for similar American success.

Blaubeuren, Germany

Population served, 20,000
Type of plant, windrowing of shredded refuse

Blaubeuren is a small community in the Alb Mountains of Germany. A large cement plant in the city uses the calcareous rock of the surrounding area as raw material for cement manufacture. Dr. E. Spohn, mill manager and part owner, has long believed in returning the ore-stripped land to agricultural productivity and has advocated and been demonstrating the value of compost from municipal waste for this reclamation.

Blaubeuren does not produce enough compost to reclaim the land at the rate it is being consumed, composting is rather expensive for such a small community, and no tangible, direct measure of the value of land reclamation is yet available; still, the concept of this reclamation and the idealism of Dr. Spohn are highly commendable. Not only is Dr. Spohn personally knowledgeable in composting technology, but he has equipped his cement manufacturing operation with a research laboratory and an experimental farm for the purpose of studying this special field of compost utilization. Hopefully, his ideas and findings will develop into a new avenue of compost utilization.

The Blaubeuren compost plant itself is small and unpretentious. The incoming raw domestic refuse is run through a Dorr-Oliver rasper. Burnable uncompostable refuse is disposed of in a simple incinerator. The raw rasped refuse is piled into windrows and cured, with one or two turnings in 3 to 6 months. Most of it is then used in the land reclamation research discussed above. Sewage sludge is sometimes added to the ground refuse before it is put into windrows, but, since the sewage treatment plant is some distance away, the sludge (cake or slurry) must be trucked in.

FIGURE 6. Blaubeuren compost plant with freshly ground refuse ready for composting.

FIGURE 7. Windrow of cured, ready-to-use compost.

Duisburg-Huckingen, Germany

Population served, 90,000
Type of plant, Dano

Duisburg is a major industrial city on the western end of the Ruhr River. The city had been having trouble with sewage sludge disposal and decided that composting domestic refuse plus sludge could be economical and satisfactory. Therefore, a two-drum Dano plant was built at one of the sewage treatment plants, and refuse from 90,000 of the 400,000 inhabitants is converted into compost.

Incoming raw refuse is handpicked for glass and rag salvage, and iron is removed by a magnet. The refuse, otherwise untreated, is then put into the 11-foot-diameter 60-foot-long Dano drums, along with sewage sludge, and tumbled for 3 to 5 days. The fresh compost is sieved and piled outside to cure. The noncompostable sieve scalpings are buried.

This plant has had trouble with odors from the composting operation. The plant, once in an undeveloped area, is now surrounded by upper-middle-class apartments. At one time, odors from composting (anaerobic conditions within the Dano drum) were so objectionable that the plant had to be shut down in summer when the incoming refuse was wettest. (In winter there are fewer vegetable and garden trimmings, and the ash content is higher.) The odor problem has been solved by a combination of techniques. First, the sewage sludge is thickened or partially dried to add a minimum of moisture to the system. Even then, only one-third of the population equivalent of sludge can be added in summer, and one-half the population equivalent is added in winter. In addition all the exhaust ventilation air of the building and of the Dano drums is scrubbed through a soil filter. This filter consists of a buried perforated pipe covered with earth and cured compost; the filter, approximately 10,000 square feet in size, filters about 7,000 cubic feet of air per minute.

The cured compost is usually rescreened, and may be ground or crushed and sieved again, resulting in a fine-textured, homogeneous, acceptable compost. It is sold primarily for gardening, nursery, and landscaping use, with none going to general agriculture. The selling price was reported to be DM 5 per metric ton ($1.15 per short ton), and 8,000 to 10,000 metric tons (9,000 to 11,000 short tons) are made per year.

It is interesting that over three-quarters of Duisburg's domestic refuse, plus all the commercial and industrial refuse, is handled other than by composting. At present this refuse is being landfilled, but Duisburg is presently planning an incinerator with power generation. The plant engineer felt that the composting operation will probably be no more expensive than incineration, and that compost will continue to be manufactured as long as there is a market for it.

FIGURE 8. Blaubeuren research field on mined-over land.

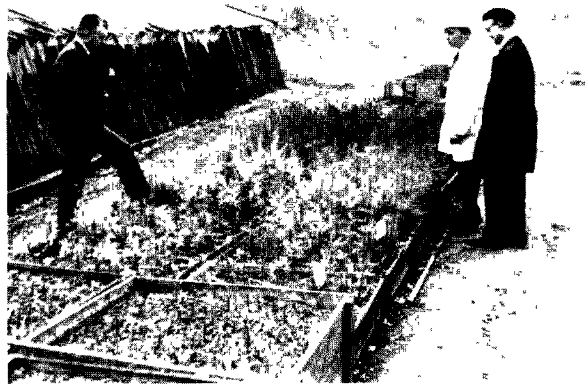


FIGURE 9. Laboratory plots on compost utilization.

Heidelberg, Germany

Population served, 30,000
Type of plant, Multi-Bactor compost tower

Heidelberg is the world-famous university city in southwest Germany. The city and its environs contain about 160,000 residents, including some 5,000 U.S. servicemen with families. Twelve years ago city engineer O. Horstmann began investigating composting as a method of processing the city's domestic refuse. The first idea was to sort, rasp, and ballistically separate the refuse and then place it in large windrows (about 35 feet wide and 20 feet high). Anaerobic conditions within the windrows caused foul odors, and it was difficult to turn the windrows. In 1962, therefore, a mechanical composting tower, the Earp-Thomas Multi-Bactor unit was installed and is working satisfactorily. Today this unit is making about 2,000 cubic meters (2,600 cubic yards) of compost per year.

Sewage sludge is added to the Door-Oliver rasped refuse and conveyed to the top of the eight-stage 20-foot-diameter 35-foot-high composting tower. A vertical shaft turns plows on each stage. The refuse is thus stirred continually, and it gradually drops from stage to stage through holes in each stage. The shaft and plows operate 8 hours per day, and the refuse

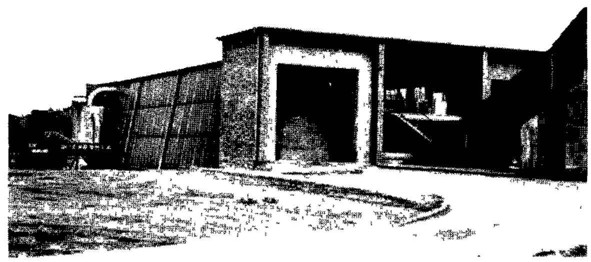


FIGURE 10. Duisburg-Huckingen compost building. Air exhaust mechanism is at rear of building.

FIGURE 11. Hand salvaging of glass and rags. One of the two Dano drums is in the background.

FIGURE 12. Baling of the salvaged metal.

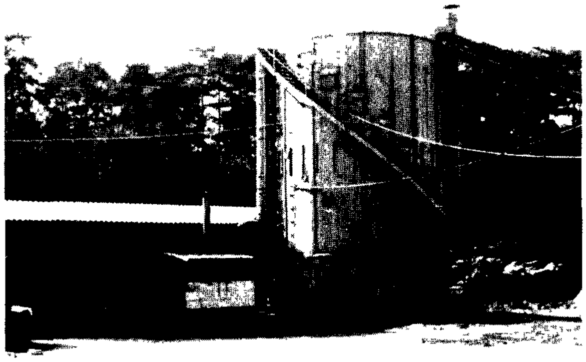


FIGURE 13. Heidelberg Multi-Bactor composting tower.

FIGURE 14. Compost storage at Heidelberg.

residence time within the tower is 3 days. The removed compost is sieved, and dropped onto an impact separator known as a secator. Glass, slag, and hard objects bounce one way, while the high-quality and softer compost rolls the opposite way. The compost is stockpiled temporarily, until it is taken away by the wholesaler, but longtime curing does not appear to be necessary.

The wholesaler pays DM 13 per cubic meter (about $2.50 per cubic yard) for the compost. He arranges to sell and transport it, and sometimes even to apply it. Essentially all of the compost is used for home gardens and landscaping projects. The wholesaler does dispose of all the 2,000 cubic meters (2,600 cubic yards) per year, but that appears to be the limit of the market although Heidelberg could make more compost by processing more of the city's domestic refuse.

FIGURE 15. Schweinfurt composting plant. Piles in foreground are ground compost awaiting shipment.

Schweinfurt, Germany

Population served, 85,000
Type of plant, Caspari-Brikollare

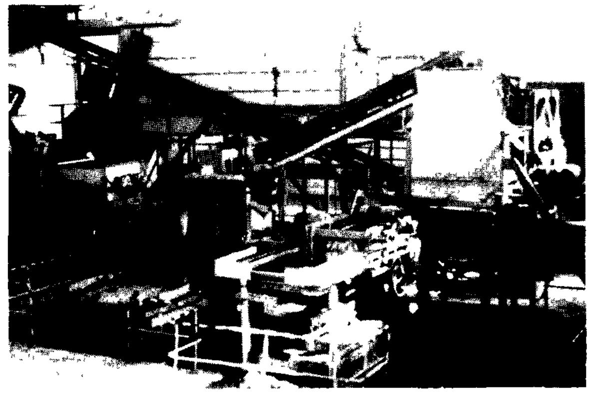


FIGURE 16. Interior of compost briquetting building.

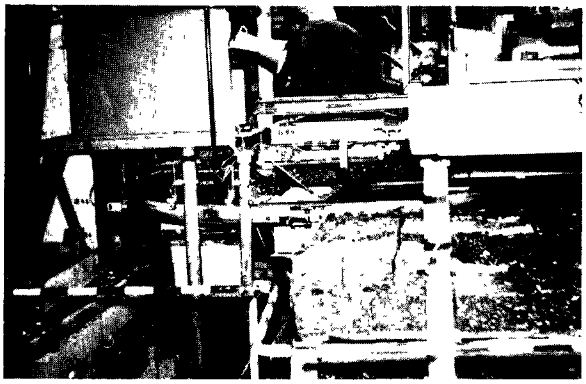
A new process, the "Brikollare Verfahren," or briquette process, is used to make compost at a plant erected in Schweinfurt in 1965. Previously, all municipal solid wastes, including industrial waste from two large ball-bearing manufacturers and one heavy-machinery fabricator, were buried in a landfill. That was changed with the construction of a $1,000,000 composting plant for domestic and commercial waste and a $1,250,000 incinerator for industrial waste.

The incoming domestic and commercial refuse is elevated from the receiving bunker by a belt conveyor. One man inspects the refuse as it is conveyed and removes materials that might damage the mechanisms, but he does not really salvage any material. Iron is removed by a magnetic separator, and then the refuse falls into Dorr-Oliver raspers for shredding. The shredded refuse is then run through a ballistic separator, where gravel, broken glass, and similar hard, heavy material is removed. The ground compostable refuse is then elevated to a surge tank.

Meanwhile, digested sewage sludge from the city's treatment plant is vacuum filtered to increase the solids content from 12 to 30 percent (nearly three-quarters of the water in the sludge is removed). The dewatered sludge is mixed with the ground refuse in an auger conveyor and conveyed to the briquetting machine. Here, an elaborate machine produces briquettes, approximately 15 inches by 9 inches by 6 inches in size, that have a "tunnel" on the underside. These are placed automatically on pallets that are moved to a "curing shed," where the actual composting takes place. The briquettes quickly heat to 130° to 140° F (55° to 60° C), a surface fungal growth develops, and the briquettes both dry out and compost. The salient feature of the process is this concurrent biological-physical change. The metabolic heat of composting promotes surface drying, while the compacted nature of the refuse caused by the pressing of the briquettes allows capillary transfer of moisture from the center to the surface. Concurrently, as moisture is removed, air enters the capillaries of the briquette and sustains the aerobic fungal and bacterial organisms that attack the refuse and convert it to compost. The close stacking of the individual briquettes, along with their tunnel form, gives adequate opportunity for air transfer while still conserving the heat of composting. Even the outside-corner briquettes attain a temperature of 120° to 130° F (50° to 55° C). In the curing process the moisture content drops from about 65 to about 13 percent (wet weight basis).

The cured briquettes are stacked outside in a yard like normal building bricks. In the fall of the year, when compost can be marketed to nearby grape farmers, the briquettes are run through a simple hammermill, and the finished compost is sold.

The impressive features of this Caspari process are the odor-free operation of the biological-



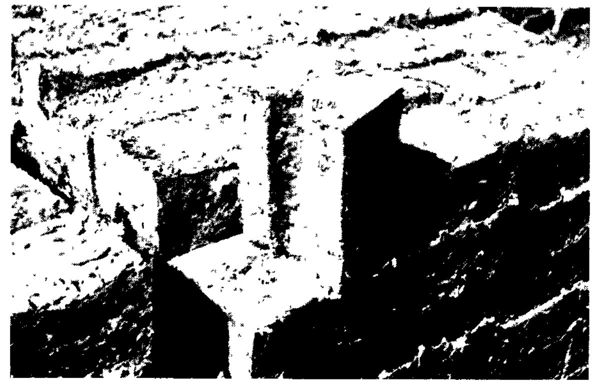


FIGURE 17. Closeup of briquetting machine.

FIGURE 18. Briquettes stacked on a pallet in the curing room.

physical composting process and the minimal land area that is needed. Additionally, the vacuum filtration of the sewage sludge makes possible the disposal of both domestic refuse and sewage sludge. Some 10,000 metric tons (11,000 short tons) of compost are produced each year. At the beginning the selling price for the compost was pegged at DM 17 to 20 per metric ton ($3.85 to 4.50 per English ton), but the price was recently reduced to DM 8 per ton ($1.80 per English ton), and the market for compost was improved.

Compost made by this new process is of good quality, but probably is no better or worse than compost made by any other process. The quality of compost depends upon how much grinding, screening, sieving, ballistic separating, and similar physical upgrading are done. This upgrading can be done after composting, as in the Dano process, or before, as in the Caspari. Probably neither process offers any great economy over the other. The Schweinfurt operation appears to be quite economical of labor, but amortization of the large capital investment is a significant cost.

St. Georgen, Germany

Population served, 14,000
Type of plant, windrow of ground refuse

St. Georgen is a small spa, or resort town, in the Black Forest, southwest of Stuttgart. The city's small compost plant takes the community's domestic and commercial waste (there is no industry other than tourist) plus sewage sludge, and converts it into compost. The refuse is handpicked for salvageable items, iron is removed by a magnetic separator, and the refuse is ground with a Bühler hammermill. Noncompostable material (mostly commercial refuse) is burned in a 1.5-metric-ton-per-hour (1.65-short-ton-per-hour) incinerator, and the ash is returned to the freshly ground refuse. This refuse, plus sewage sludge from the adjacent sewage treatment plant, is arranged in windrows (about 10 feet wide and 4 feet high) and cured for 3 to 6 months, usually with three turnings.

About 1,400 cubic meters (1,800 cubic yards) of finished compost are produced each year, and sold at DM 10 per cubic meter ($1.90 per cubic yard) to home gardeners, truck-crop farmers, and forestry nurseries. The net cost to the city was not reported, but would appear to be rather high because of the small volume of waste handled plus the investments in both incinerator and composting equipment. The plant is neat and well-run.

Figure 19. Outside storage of the composted briquettes, *awaiting final grinding and sale.*

Figure 20. St. Georgen composting plant and sewage treatment plant.

Figure 21. Windrow curing of St. Georgen compost.

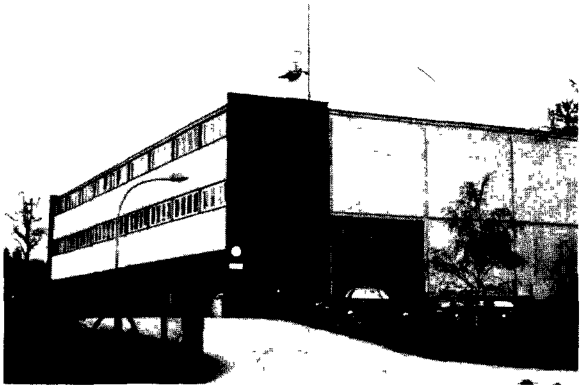


FIGURE 22. Stuttgart Möhringen composting plant.

FIGURE 23. Curing or compost in closely packed windrows.

Stuttgart (the suburb of Möhringen), Germany

Population served, 75,000
Type of plant, windrow of ground refuse

The Stuttgart composting operation is similar in concept to those of Duisberg and Heidelberg. That is, public works officials recognized that composting was a feasible avenue of management for a portion of the city's domestic refuse, though not for all of it (Stuttgart is a city of 650,000). Therefore, a conventional windrow composting plant was built in 1959 in the suburban district of Möhringen. This plant is the only one in Germany that was not conceived to take sewage sludge also. The incoming refuse is conveyed from the storage bunker over a picking belt. When salvage prices are favorable, glass, cardboard, clean paper, or rags can be picked off. At present only iron is removed with an overband electromagnet. The refuse goes to a Dorr-Oliver rasper and is abraded. It is then transported by truck some 50 to 100 yards to the windrow area, where composting occurs. The material is turned twice within about 3 months.

There has been no high-pressure selling program to dispose of the compost. Citizens of Stuttgart may come to the plant and take, at no charge, small amounts of the material for their homes and gardens. Most of the compost, however, is sold to neighboring grape farmers for about DM 5 per metric ton ($1.15 per short ton).

Composting is looked upon at Stuttgart as a public service, not only to satisfy homeowner wants but also to demonstrate the principle of conservation. It is recognized and accepted by the city government that composting costs more than alternative waste disposal methods but that it is an appropriate community expenditure, the same as supporting city parks or museums.

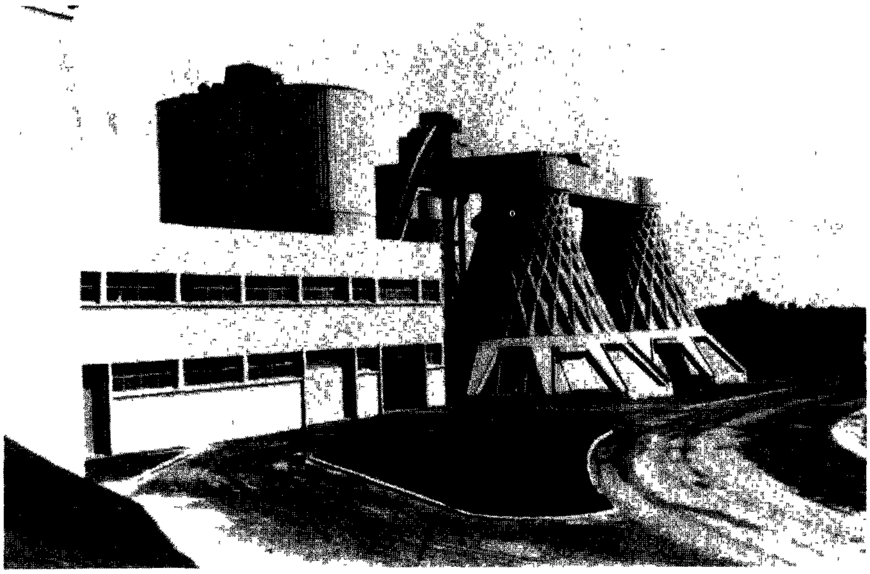


FIGURE 25. The actual plant.

Versailles, France

Population served, 82,000
Type of plant, Triga, silo type

The composting plant in Versailles (near Paris) is brand new. Regrettably, not many details were available—mostly because of language difficulties. It was inspected as a part of attendance at the INTAPUC (International Association of Public Cleansing) Conference held in Paris in June 1967.

Incoming domestic refuse amounts to some 150 metric tons (165 short tons) per day. The metal is removed with a magnetic separator, and the refuse is then ground with a heavy-duty Hazemag hammermill. The ground refuse is rough screened (scalpings go to an incinerator) and then put into the four silos, each with a capacity of 320 metric tons—about 700 cubic meters (350 English tons—915 cubic yards). It was unclear whether the daily input is divided among the four silos or whether one silo is used for each day's waste, in rotation. In any event, some air is blown through the silo for aeration, and each silo is equipped with a bottom unloading device. The removed compost is sieved a second time and then piled outside for curing and to await sale.

This plant, evidently privately owned (by the Triga Co.), charges the city of Versailles 4 FR per metric ton (about $0.73 per short ton) for domestic waste accepted. (This seems very low and appears to be a promotional price which does not reflect the actual cost of waste disposal.) The price and the market for the finished compost were not defined. The plant is new, and perhaps the market has not yet developed.

The plant is very attractive and is apparently a well-engineered unit.

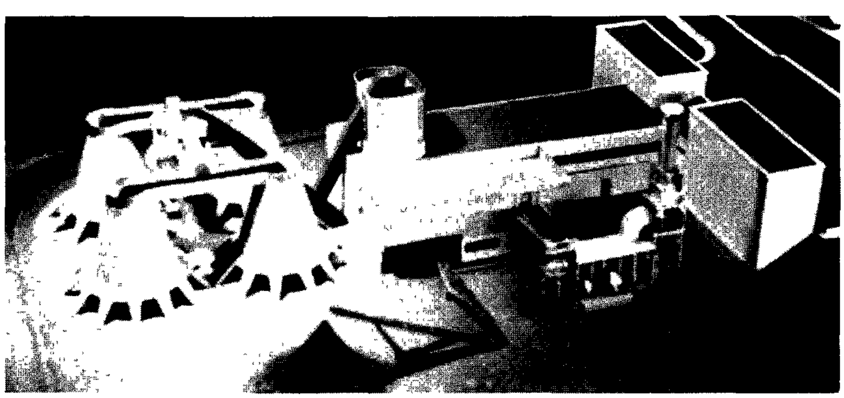


FIGURE 24. Model of the composting plant at Versailles, France.

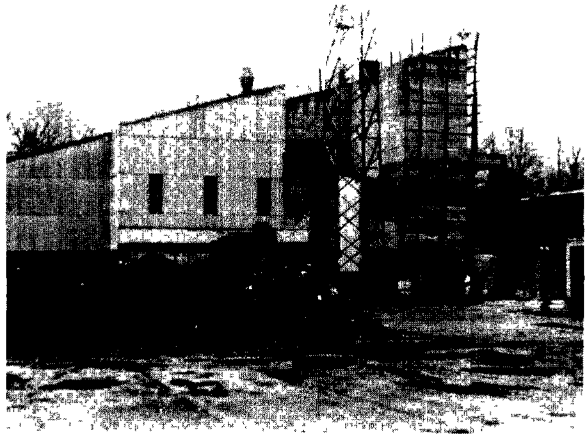


FIGURE 26. Composting plant at Buchs, Switzerland. A new incinerator building is being constructed adjacent to the compost building.

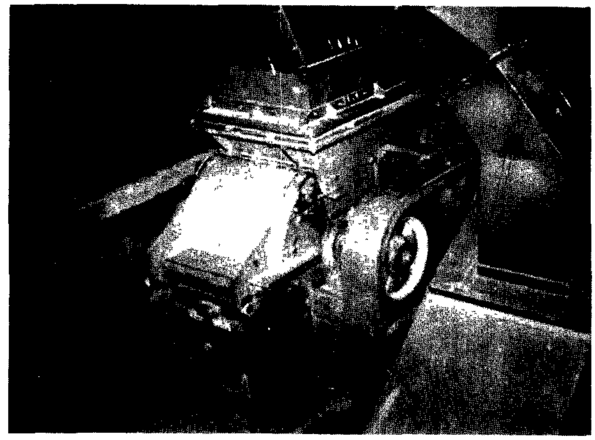


FIGURE 27. Bühler mill for grinding the refuse.

Buchs, Switzerland

Population served, 40,000
Type of plant, windrow of ground refuse

The Buchs compost and waste-burning plant in Switzerland serves some 40,000 people in 16 communities in two countries (Switzerland and Lichtenstein). The actual plant is located in the town of Buchs, population 5,000. Domestic refuse is brought to the plant by municipal vehicles of the various communities. (Commercial and industrial refuse and construction debris are hauled to a regional landfill.) Both the market for compost and the facilities of the composting plant are not adequate for all the received refuse to be converted to compost, so a substantial fraction is burned in open piles—with concomitant smoke and nuisance. A new incinerator is presently being constructed, and it is expected that the majority of the domestic refuse received by the plant will then be burned. Composting will be continued to the extent of its marketability—primarily to grape-growers in the area.

The incoming refuse is first ground with a Bühler coarse hammermill. Iron is then removed with a magnetic pulley, and the refuse falls into a second hammermill for fine grinding. The refuse is then sieved. (Scalpings are buried in the industrial-waste landfill site.) Sewage sludge can be and is mixed with the sieved, freshly ground refuse, and the material is then placed in windrows, which are usually turned twice during the following 4 months.

No really valid idea was developed of the communities' needs for composting and the costs and marketability of compost there. The demand, however, did not seem very great.

FIGURE 28. Ground refuse at the beginning of composting.

FIGURE 29. Compost windrows at Buchs.

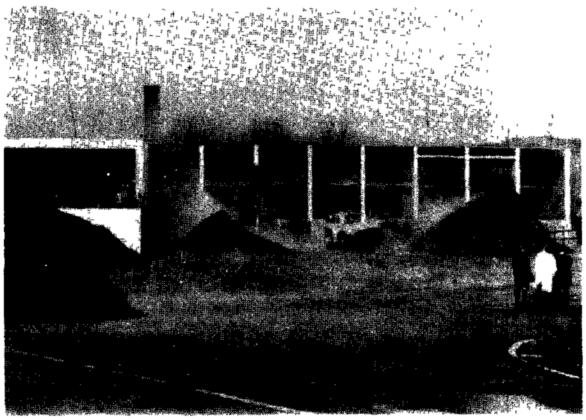


FIGURE 30. Hinwill, Switzerland, composting plant. Vapor coming from piles is primarily snowfall onto the warm compost.

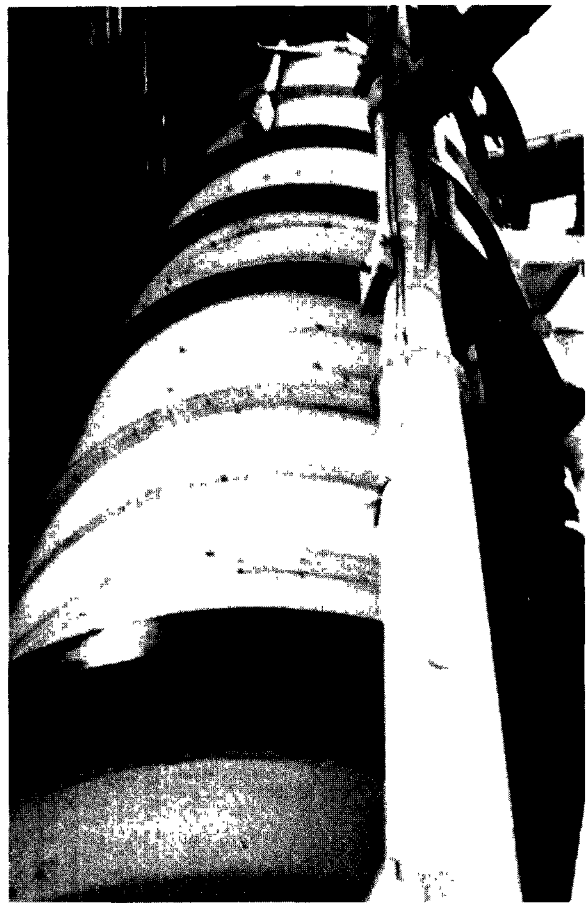


FIGURE 31. View along the Dano drum.

Hinwill, Switzerland

Population served, 100,000, in 23 surrounding communities
Type of plant, Dano

Like most Swiss plants, the Hinwill composting plant serves a number of small communities, Hinwill itself has a population of 3,500. Thus, the wastes are primarily of domestic origin, with only a small volume of commercial and industrial refuse needing disposal. The incoming refuse is run over a magnetic pulley and deposited in the Dano drum along with thickened sewage sludge. The drum itself is 11.5 feet in diameter by 90 feet long, and the refuse has a residence time of 2 to 3 days. The discharged material is run through a coarse and a fine Bühler hammermill, sieved, and then stored outside for final curing. The material not passing through the sieve is burned on site. This incinerator is too small and has created some operational problems. As at the Dano plant in Duisburg, a soil filter system for the ventilation air had been installed and appeared most successful. The compost is sold primarily for grape vineyards, but the marketing situation did not seem good. It appears that lack of demand for compost is the stumbling block to Swiss success in composting.

FIGURE 32. Soil filter for removing odors from the exhaust air.

FIGURE 33. Composting plant at La Chaux-de-Fonds, Switzerland. Building on left, and compost windrow on right.

FIGURE 34. Dano Egsetor part of the compost preparation equipment.

La Chaux-de-Fonds, Switzerland

Population served, 15,000 (estimated)
Type of plant, original Dano
(built in 1953)

This plant is located in the western (French-speaking) section of Switzerland, in the city of La Chaux-de-Fonds, population 43,000. The plant is one of the original Dano installations, with a fast-rotating drum followed by a drum screen. The incoming domestic and commercial refuse from about one-third of the city is put into the conventional Dano drum (at La Chaux-de-Fonds it is about 9 feet in diameter and 40 feet long). The drum is rotated at about 2 rpm for a half hour, to abrade, crush, and grind the refuse. The material is then conveyed to a drum screen, called an Egsetor. This unit is 9 feet in diameter and 12 feet long. An outer shell and an inner cage or sieve of pipes rotates; the crushed, ground, fine material falls through the pipes while cans, plastic, and large inert materials are retained on the pipe screen. The two components are periodically removed from the Egsetor to separate piles, the compostable refuse is skip loaded to a windrow, and the inerts are buried.

Presently the compost is being sold to small truck-crop farmers in the area or transported 30 or more miles for home-garden sales. The plant is old, and the compost market is poor, so that this composting operation will probably be shut down before long.

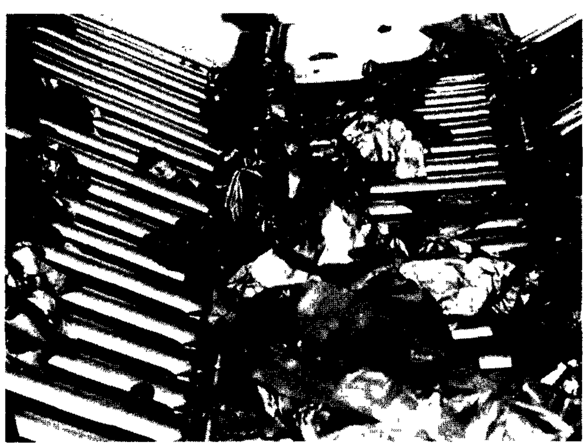


FIGURE 35. Interior of the Egsetor showing the pipe screen which holds back the noncompostables.

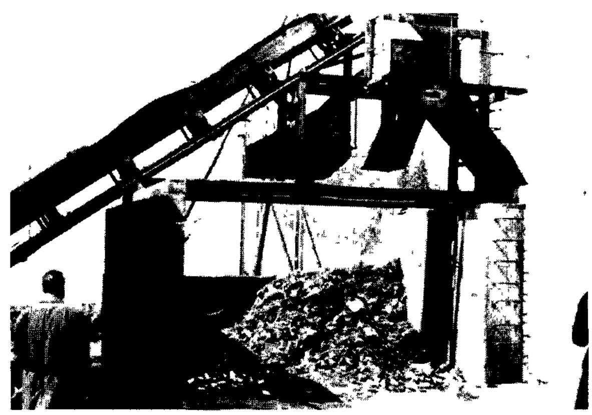


FIGURE 36. Elevator and diverting chute for noncompostable discard material (center) and refuse for composting (right).

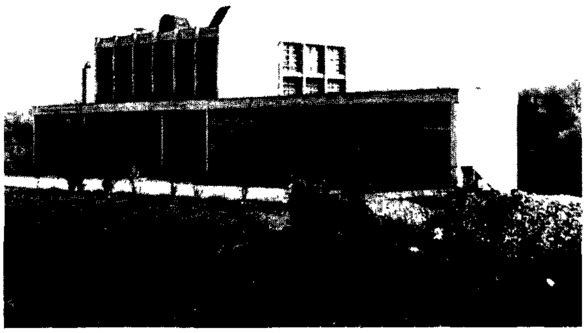


FIGURE 37. Composting plant building at Turgi, Switzerland.

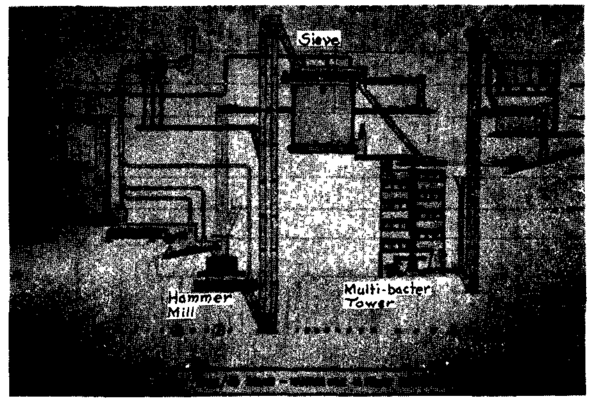


FIGURE 38. Schematic drawing of the composting plant.

Turgi, Switzerland

Population served, 70,000, in 10 communities
Turgi population 5,000
Type of plant, Multi-Bactor compost tower

This plant is similar to the Heidelberg Multi-Bacto composting operation except that it is enclosed within a building and uses different makes of auxiliary equipment. At the time of the visit one of the composting towers was out of operation for replacement of the plows that mix and move the refuse.

After iron is removed magnetically, the refuse is ground with a Hazemag hammermill and then sieved before being elevated to the Multi-Bactor tower. After residence in the tower, the compost is sieved again and prepared for market. No curing is provided. A considerable volume of the Turgi compost is put into heavy-duty plastic sacks for sale to homeowners. It appeared that less than half of the incoming refuse is made into compost, the division being made on the screen after the grinding. The grinding of the raw refuse reduces volume greatly, so that it can be landfilled more easily.

Despite the repairs to keep the plant in operation for a few years more, the decision has been made to incinerate refuse in the future. A large two-furnace incinerator installation will be built adjacent to the présent compost plant. Burnable industrial and commercial refuse, as well as domestic refuse, will then be handled by the incinerator plant. The composting operation will probably continue to the extent that compost can be sold at a price that defrays the extra costs of composting over incineration.

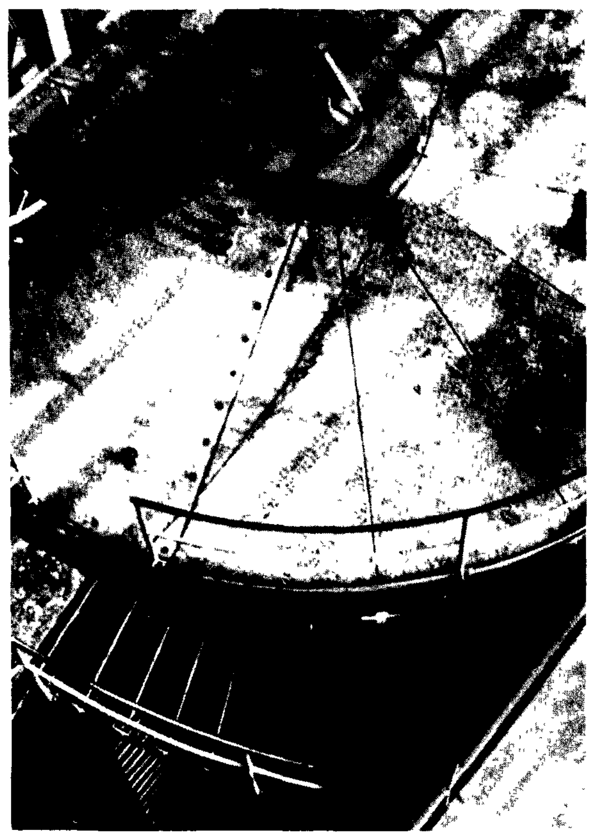


FIGURE 39. View of the top of the Multi-Bactor composting tower.

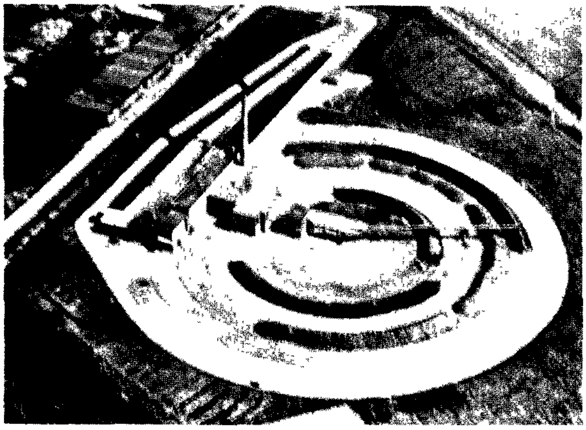


FIGURE 40. Aerial view of the compost plant at Arnhem, Holland.

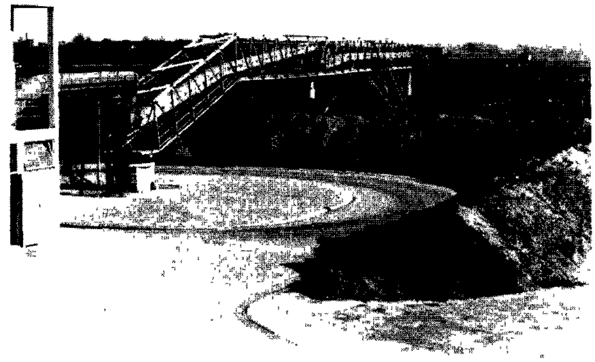


FIGURE 41. Pivoting belt conveyor to distribute fresh-ground refuse into circular windrows.

Arnhem, Holland

Population served, 134,000
Type of plant, Windrow, of ground refuse

Composting is much more successful in Holland than in Switzerland, because compost utilization is more highly developed. Thus, plants like that at Arnhem are models of productiveness, efficiency, and cleanliness. The incoming domestic and compostable commercial and industrial wastes are run over a magnet for iron removal, and then shredded in a Dorr-Oliver rasping machine. The unshredded material from the rasp, plus burnable bulky objects and noncompostable industrial waste, is burned in an onsite incinerator (an operation similar to that at Schweinfurt).

The shredded refuse from the rasping machine is placed in concentric windrows by a pivoting belt conveyor. The engineers at Arnhem are presently experimenting with removing plastic film from the freshly ground refuse by means of an air blast that blows it out while the refuse falls from one belt to another. This apparently holds promise but is far from being fully worked out.

Not all the freshly placed refuse is allowed to cure at the compost plant. At some periods of the year nearly all of the freshly ground refuse is bought by specialty farmers in the area and used in hotbeds. Like horse manure of old, this freshly ground refuse undergoes biological stabilization, producing heat and keeping the plant-bed warm.

Freshly placed refuse that is not sold immediately is piled into windrows about 4 or 5 feet high. After the initial heating the windrow is turned and piled higher, into a windrow 12 or 15 feet high, and curing is continued.

The compost is not sold directly by the City of Arnhem, but by the VAM organization. The officials at Arnhem calculate that the city's domestic refuse could be disposed of by dumping or landfilling at a cost of f 2.50 (about $0.75) per capita per year. Composting net costs are higher, about f 3 (about $0.90). The government and the citizens approve of this greater expense on the basis of pollution control, conservation of resources, and long-term esthetic benefit to the country.

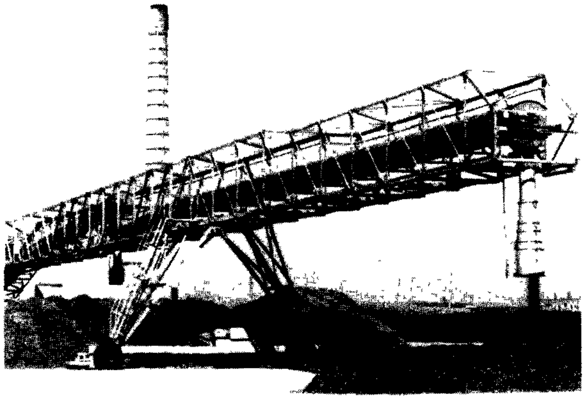


FIGURE 42. Discharge end of pivoting belt conveyor.

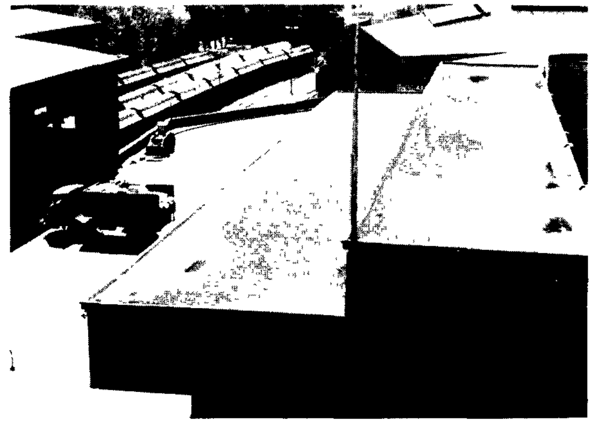


FIGURE 43. Garbage transfer station at Den Haag, Holland. The special railroad cars are in the background.

Wijster, Holland

Population served, 1 million plus: Den Haag and other communities
Type of plant, Van Maanen system

The Wijster compost plant, owned and operated by the VAM, is in the heath area of northwestern Holland, about 90 miles from Den Haag, source of most of the refuse. Composting has been conducted at Wijster since 1927. Domestic and commercial refuse, plus some industrial waste, is transported to Wijster by special railroad cars from Den Haag and the other contracting cities. The railroad cars are unloaded by gravity from viaducts above the composting area. The untreated refuse is wetted down with a sprinkler system and allowed to begin composting. After 1 or 2 months the refuse is turned with large grab cranes, with two or three turnings being made during the composting period of 6 to 8 months. When the composting is completed, the refuse is conveyed into the processing plant by cable-operated railroad cars. At the plant the refuse is sieved, crushed, and resieved. Several grades of compost are manufactured, including some with peat moss added. The noncomposted residue is transported to an open-dump disposal site, where it is distributed and compacted. This is not objectionable, since the material is the inert residue from composting. There are some vector problems at the actual compost site: rats and flies are attracted by the freshly placed refuse. The Wijster area is relatively uninhabited, however, and aside from the vector problem the composting operation as a whole seems very satisfactory.

Den Haag is presently constructing a large incinerator with power-generation facilities and will no longer ship raw garbage to Wijster. The VAM organization has therefore signed contracts with other, smaller cities and will probably continue to produce nearly as much compost as previously.

FIGURE 44. Loading of the railroad cars.

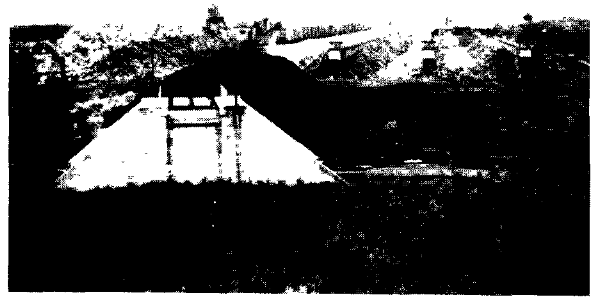


FIGURE 45. Overview of the composting plant at Wijster, Holland, which receives Den Haag's and other cities' garbage. Note railroad cars on elevated viaduct.

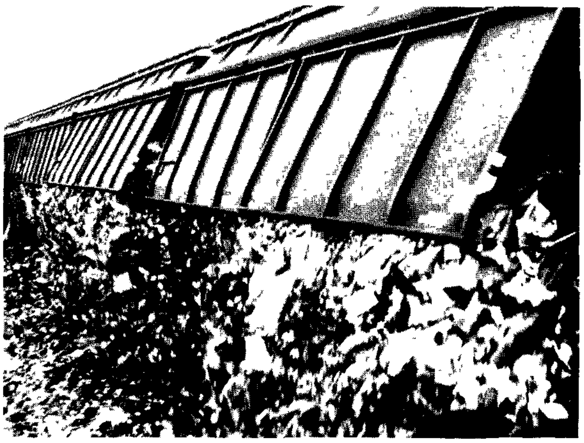


FIGURE 46. Unloading of the railroad cars.

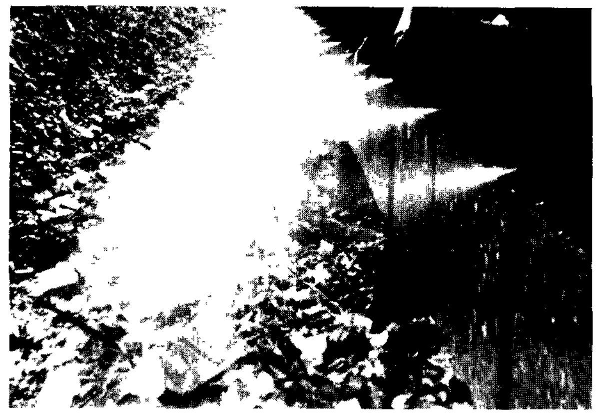


FIGURE 47. Sprinkling of the freshly unloaded garbage.

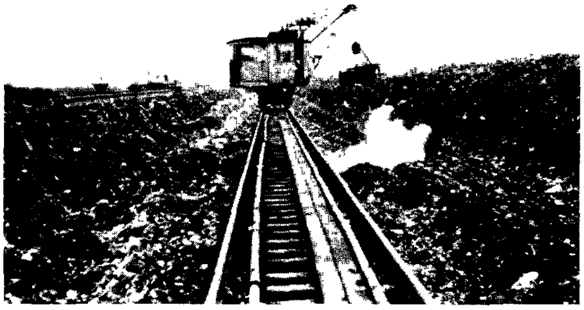


FIGURE 48. Cranes used for turning the refuse for faster and better composting.

FIGURE 49. The composting windrow at Wijster.

Compost Utilization in Europe

The theme of this section has been introduced in the discussions of the individual composting plants. More detailed discussion is required, however, since the subject is so important to any future decisions on composting in the United States.

The nine composting plants of West Germany make compost from less than 1 percent of the domestic refuse generated in that country. The situation is more favorable in Holland, where one-sixth (17 percent) of the nation's refuse is made into compost. France, Switzerland, and Italy also compost domestic refuse, but the quantity or percentage figure is not available. All countries could produce more compost, and would produce it if it could be marketed and utilized. At least in Germany, Holland, Switzerland, and France, however, expansion of composting operations is slow because there is little additional opportunity to utilize the compost economically. (The present emphasis in solid wastes processing in those countries is on incineration, with the production of steam or electricity.)

Compost has its major market only in luxury agriculture. It is not used extensively in general, normal, or basic agriculture, and does not seem to be economically marketable there. In 1927 the Dutch located the composting plant for the Den Haag refuse 90 miles away, in Wijster, in the middle of the heath lands. The intent was to reclaim this sandy, marginal land with compost. In the early years the compost was distributed to the nearby land, and some improvement was brought about. But farmers today have learned to farm with chemical fertilizers. Organic material is not an important factor except for erosion control on steep slopes. Today, most of Wijster's compost is backhauled to the populous, intensively cultivated coastal region of Holland and used in luxury agriculture. The actual market for Dutch compost in 2 recent years has been tabulated (table 1).

TABLE 1. SALES DISTRIBUTION OF COMPOST FROM MUNICIPAL REFUSE IN HOLLAND

Outlet	Year 1961	Year 1965
Forestland improvement	2.4	0.6
Basic agriculture (field and row crops, and for pig litter)	34.4	16.4
Fruit farming	6.5	6.3
Hotbed vegetable farming*	11.6	13.0
Greenhouse vegetable farming	7.9	8.4
Flower and flower bulb production (greenhouse and outdoor)	11.7	17.6
City park, sportfield, and recreational use	25.5	37.7

*Hotbed compost is freshly ground domestic refuse. It is used on the bottom of the hotbed in place of horse manure. The biological process of composting generates heat that makes the hotbed crop grow. Hotbed crops in Holland are cucumbers, melons, and green peppers.

In Germany too, the marketing of compost is luxury oriented. About 60 percent of the compost is used to reduce or prevent soil erosion on steep hillside vineyards that produce the grapes for Germany's fine-quality wines. Although some people consider wine a basic food, the vineyards in southwest Germany on which the compost is used primarily produce wines that are used for social drinking. Organic matter has always been needed on these hillsides; in former years the farmers used animal manures and crop residues. Today, such organic materials are less available in the immediate area, because of the mechanization and specialization of agriculture, and the substitute is compost from municipal refuse.

Most of the rest of German compost is marketed for home gardens, park and recreation uses, via similar luxury avenues. There is, of course, nothing wrong with this—it is actually a very good thing that man's wastes can be converted to give him pleasure; but the size of the market for compost used this way is strictly limited. The average German citizen produces about 500 pounds of domestic refuse per year; between 150 and 200 pounds of compost can be made from this amount of refuse. Utilization of 150 pounds of compost per citizen per year in luxury agriculture—or in all agriculture—seems unlikely. Other markets for compost are limited.

The Blaubeuren compost plant makes 1,500 to 2,000 short tons of compost per year, it is being used for mineland reclamation. It was also indicated that in some years some German compost is used for fruit production (cherries, peaches, and fresh grapes) and for market vegetables, but no information was obtained on the actual quantity so used.

The Swiss utilization of compost is similar. Most of it is used on vineyards, but marketability has been poor. Attempts to move into the home-garden market have met with some success, but, here too, the volume that can be moved via this avenue is limited. Two of the four visited plants—Buchs and Turgi—have plans to install or are installing refuse incinerators and in the future will produce compost only to the extent that it is readily marketed.

There has been a good deal of research on compost utilization in basic agriculture, as discussed in the next section. The point here, however, is that, even with promotional research, compost is not being used extensively in basic agriculture.

This is regrettable, for compost could be quite cheaply produced for this use. It would not need to be so refined, with fine sieving, milling, and grinding. Yet, compost is not used in basic agriculture. The reason is that it does not pay. The nutrients in a ton of compost are almost negligible; a typical compost contains only 0.5 percent nitrogen, 0.4 percent phosphorus, and 0.2 percent potassium. Farmers can buy and apply chemical fertilizers more cheaply than they can apply "free" compost or even livestock manure.

Advocates of compost point out that the important aspect of compost is the organic matter content, not the nutrients. It is the organic matter that improves the physical properties of the soil, so important in reducing or eliminating erosion on the steep vineyard slopes. In general agriculture, however, soil erosion is prevented more economically with contour farming and similar practices than with compost addition. Under today's economic conditions a farmer of corn, cotton, or general row crops just cannot justify the use of compost.

In summary, then, compost utilization today in Europe and the United States is limited to luxury agriculture. A later section of this report proposes a new avenue of approach, based on nonbeneficial utilization. This will probably be the real future for compost use.

European Research in Compost Manufacture and Use

A number of lines of research in composting have been conducted in Germany in recent years. Similar work done in the other European countries was not investigated during this study. German composting research has been in such diverse fields as engineering technology (Stuttgart), public health and pathogen survival (Giessen), use in strip minefield reclamation (Bonn), use in vineyards (Bad Kreuznach), and use in general agriculture (Braunschweig).

Engineering Technology—Stuttgart. The European leader in the engineering aspects of solid waste management has been Dr. F. Pöpel, professor of sanitary engineering at the University of Stuttgart. A part of the research effort of his Institute and of his personal work has been in composting technology. This has encompassed both basic studies on biological processes of composting and practical research in designing composting plants for municipalities.

Professor Pöpel has long felt that the composting process could be substantially accelerated and made more economical if partially composted refuse were recycled. The concept is similar to the activated sludge process of sewage treatment. Laboratory results at Professor Pöpel's institute have proved the merit of this approach. Actually, the biological process is but one part of producing compost. The materials-handling part is equally important, especially with regard to the removal of noncompostables and grinding and fine-sieving to meet today's market. Professor Pöpel has also been concerned with this, but lack of support for graduate students has limited recent activity in this area. It is interesting to note, however, that the Caspari-Brikollare process of composting at Schweinfurt is an outgrowth of earlier research on materials handling by Professor Pöpel.

Although Professor Pöpel's philosophy and approach are very important, it appears that the more critical part of the composting problem today is utilization. Consequently, no indepth study was made of Professor Pöpel's activities.

Public Health Problems With Compost—Giessen. The Institutes of Human Health Protection and Animal Health Protection of the Justus Liebig University at Giessen have made an important contribution to knowledge on composting and pathogen carryover. Giessen research is the basis for present German regulations on health hazards from the use of compost-sludge mixtures. Since public health problems will be of concern if compost is used in the United States on a major scale, it is appropriate to describe the German work in some detail.

In order to prove the positive killing of pathogenic organisms by composting, the raw refuse must be known to contain them. But finding a few residual living microorganisms in a large sample after composting is like testing for *E. coli* in treated water—a particular grab sample may or may not contain the organism. Multiple samples and "most probable number" (MEN) statistics are therefore used in water testing. For pathogenicity tests with compost, such negatively oriented procedures are inappropriate. Rather, from an artifically implanted known number of pathogenic organisms, one must determine how many are recovered at various stages of composting. Dr. D. Strauch of the Institute of Health and Infectious Diseases of Animals has done exactly this by means of an "inoculated bag" technique.* In this test a 100-gram sample of ground, raw refuse was put inside a bag of Perlon® synthetic fiber cloth, which is not decomposed by composting. The mesh of the bag is similar to that of shirt broadcloth, preventing loss of the refuse yet allowing air to move freely through it. Before the bag is closed, a sealed vial of pure culture of a particular pathogen is added. The pathogens in the vial are thus exposed to the same temperature but not to any microbial interaction of composting, thereby measuring the pasteurizing effects of composting. The major part of the test, however, is inoculation of the 100 grams of refuse in the bag with free pathogens. A known number of pathogenic organisms are incorporated into this bag of refuse, either by injecting them with a hypodermic needle or by putting them into a gelatin capsule which melts at the composting temperature. (These careful procedures are necessary for safety.) These free pathogenic organisms are exposed both to the composting temperatures and to the symbiotic or antagonistic interaction of all the other microorganisms within the refuse.

*The complete report of Dr. Strauch's work is published as Veterinärhygienische Unersuchugen bei der Verwertung fester und flüssiger Siedlungsabfälle. *Schriftenreihe aus dem Gebiet des Offentlichen Gesundheitswesens,* Heft 18, Verlag Georg Thieme, Stuttgart, Germany, 1964. The work has been summarized in other German publications and has also been summarized in English as The Importance of Pre-fermentation in Composting. H. J. Banse, and D. Strauch. *Compost Science* 7(3): 17–22, Autumn-Winter 1966. This work has also been done relative to human pathogen problems, and a general survey of it is translated in English as Public Health and Refuse Disposal. K. H. Knoll. *Compost Science* 2(1): 35–40, Spring 1961.

In the study conducted with windrow composting, these small bags were further enclosed within a larger bag; in a study of drum composting they were protected inside a perforated steel ball to protect the bag from physical damage. Many bags were removed at various stages of composting, and the contents were cultured to determine the die-away rate of the pathogen and the duration of infection.

It was recognized that the greatest likelihood of survival would come from sporeforming pathogens, and possibly from viruses. Therefore, the pathogenic materials tested by Dr. Strauch were *Bacillus anthrax* (anthrax disease), *Salmonella enterides* (causes food poisoning), *Erysipelothrix rhusiopathise* (the swine erysipelas, a skin-lymph disease), and Psittoservirus (parrot-fever virus). In corollary work, typhus and typhoid pathogens have been tested.* The work was done at the composting plants at Baden-Baden, Heidelberg, and Bad Kreuznach, as well as at Frankfurt on an experimental mixture of landfill residue, sewage sludge, and industrial wastes.

The results show the minimum time-temperature requirement for killing pathogenic material in compost. In windrow composting, pathogens are killed in 18 to 21 days if the temperature is continuously above 55° C (131° F). Lower temperatures require a longer time, and at Frankfurt some pathogens lived after 251 days. The amount of grinding made a difference: Kills were quicker in shredded refuse. The frequency of turning was important in that it assisted in maintaining high temperatures and better contact between pathogen and substrate.

Pathogenic materials were killed in the Dano drum (using unground refuse) if held there for 5 days. Such a long detention time is not usually practical, and it was found that kill was equally effective with the normal 3-day drum dention time plus additional windrow storage for 4 days. At Heidelberg, where the refuse is ground before it is put into the Multi-

*Knoll, K. H. Public health and refuse disposal. *Compost Science* 2(1): 35–40, Spring 1961.

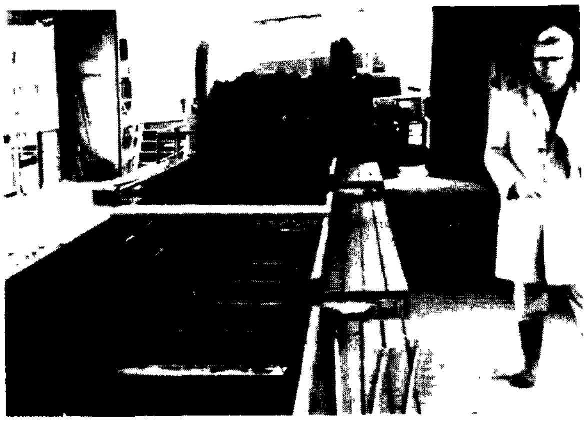


FIGURE 50. Screening operation to produce saleable compost.

Bactor tower, pathogens are killed within 24 hours.

This pathogen appraisal technique has been well worked out by Dr. Strauch and others at the University of Giessen. It appears to be directly usable for similar research in the United States.

Mineland Reclamation—Bonn. Dr. H. Kick, professor and head of the Department of Agricultural Biochemistry at the University of Bonn, has been the leader in research on the use of compost in land reclamation. Strip mining methods are used to remove lignite coal from lands west of the Rhine River near Bonn. In strip mining the overburden soil is taken off, and the lignite is then removed. The first volume of overburden is piled onto undisturbed land. Then, as the mining progresses across the countryside, the overburden of the new cut is deposited into the pit where the lignite was removed. Typical overburden depths of German lignite mining vary from 50 feet to well over 300 feet. Since these lignite fields are "dipped," they grow progressively deeper, and at some point it becomes uneconomical to strip off the overburden. At the end of the operation a substantial pit is often left, and the whole mine area is lower in elevation by the thickness of the lignite bed removed. Although German land reclamation laws require the mining company to replace topsoil to the top of the spoil area, a great deal can still be done—and must be done—to bring such mined lands back into production.

One particular piece of research work recently reported by Dr. Kick concerns a plot of land in the northwestern part of the Rhine River coal area near Cologne.* The overburden soil above the soft coal was basically a silt but also contained sand and gravel. Before mining, the topsoil contained 0.55 percent organic matter and 35 mg nitrogen per 100 grams soil. After mining, this same topsoil did have a 1 to 1.5 percent carbon content, but it was recognized to be primarily waste coal. The pH was 7.3 to 7.5. This replaced topsoil had lost its structural characteristics and was susceptible to compaction and slicking over.

Plots of 25 square meters in size (270 square feet) were treated with various kinds and amounts of organic and chemical additives and fertilizers. The basic organic materials were refuse compost, dried sewage sludge, and a peatmoss sewage sludge mixture called "Biohum." Chemical nitrogen, phosphorus, and potassium were added as appropriate. The plots were then planted the first year to mangels (a root-crop cattle feed), then to cabbage, then to winter wheat, and finally to alfalfa for 2 years. The crop yields were all related to the check plot (no organics and no chemical fertilizers). Yield in terms of the untreated yield ranged from 97 percent (where the field was overloaded by applying 125 tons of compost per acre with no balancing chemical nutrients) to 148 percent (on plots treated with 60 tons of sewage sludge plus chemical fertilizer). Nondefinitive appraisals of soil structure were made, and it was felt that the soils fortified with the organic materials had better physical properties. This avenue is being studied further in current research and, of course, is a key factor in the reclamation of such lands. An economic appraisal was also made; with present production and transport costs the crops were pro-

*Kick, H. Erfahrungen über die Kompostverwendung ur Rekultivierung in Bergbaugebieten. *Second International Congress IRGRD (International Research Group on Refuse Disposal)*, Essen, May 1962. (The Secretariat of IRGRD is at Physikstrasse 5 CH Zurich 7/4, Switzerland.)

FIGURE 51. Top edge of the Bad Kreuznach, Germany, vineyard soil erosion test plots.

FIGURE 52. View down the slope.

duced more economically with chemical fertilizers.

Much more work needs to be done on land reclamation and compost utilization. Professor Kick is continuing the work in Germany, and his results will be useful to concurrent American investigation.

Vineyard Soil Erosion Prevention—Bad Kreuznach. Most of the vineyards that produce Germany's and Switzerland's fine-quality wines are on south-facing hillsides whose slopes are often quite steep (up to 30°). The vines must be planted on the slope (not on the contour) for ease in harvesting the grapes and caring for the plants. Thus, erosion of the exposed soil between the rows of vines can be a very serious problem. For as long as farmers have been growing grapes on these hillsides, they have used organic matter to help hold the soil in place. The usual materials have been animal manures, straw, and other crop residues. With the expansion of vineyard acreage and the increased mechanization and specialization of agriculture, it has become more difficult and more costly to obtain these usual organic materials. Compost made from municipal refuse is a good substitute and has been used in rather substantial amounts. In fact, it is estimated that 60 percent of Germany's compost production is used in this manner, and compost probably accounts for 5 to 10 percent of the organic matter used in those vineyards.

Research on the use of compost in wine vineyards has been conducted at a number of places in Switzerland and Germany. Probably the most comprehensive has been (and still continues) at Bad Kreuznach, Germany. The present researcher is Dr. I. Bosse, a research scientist employed by the state (Rhine-Hessian); previously, the researcher was Dr. H. J. Banse. The research has been conducted for 9 years.

The early research efforts were concerned with making compost satisfactorily and economically. In the early years Dr. Banse worked closely with the plant operation and with the Dano Co. in proving out the drum composting system. Later, Dr. Banse cooperated with Dr. Strauch from Giessen in the pathogen survival studies covered earlier in this report.

Recent work, begun by Dr. Banse and being continued by Dr. Bosse, relates to use of the compost. Some of this work has related to the nutrient content of compost and the nutrient availability of organically enriched soils. This is a long-term study, and definitive results are not yet available.*

An especially important and conclusive compost utilization experiment at Bad Kreuznach is concerned with soil erosion. This experiment is presently in its seventh year. Figures 51 and 52 are photographs of the 30.1° slope on which catch basins are installed. Each plot is 20 square

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*I. Bosse. Humusersatz in den Weinbergen. *Feld und Wald* 23, June 4, 1965.

meters (215 square feet) on the horizontal projection; this is 23.1 square meters (248 square feet) of surface exposure. The plots are growing typical grapes farmed in the typical way except for the compost application. Compost is applied every third year at the rate of 89 metric tons per hectare (79 tons per acre); 178 metric tons per hectare (158 tons per acre); and no compost (the check plots).

The surface is covered about one-half inch deep by the 79 tons of compost, and about 1 inch deep by the 158 tons of compost. The compost is mulched into the top surface a bit, but not incorporated thoroughly.

Figure 53 shows the average yearly runoff water loss, and soil loss carried by the runoff water.

The compost acts to reduce soil erosion in three ways: The crumblike resilient compost material on the soil surface absorbs some of the energy of the falling raindrops, thereby protecting the more sensitive soil particles; the compost inherently has a high water-holding capacity—like a sponge—thereby retaining water better within the soil-compost material and reducing runoff; as the compost is biologically converted to soil humus, it promotes aggregation and textural strength of the soil particles so that they resist erosion better.

This very positive benefit from using compost on hillside vineyards is the basis of compost use by the grapegrowers of Germany and Switzerland. Compost may or may not have secondary benefits, but reduction of soil erosion is sufficient economic justification to the grape farmers today.

On a nearby test plot Drs. Banse and Bosse have run studies on the increased moisture-holding capacity of compost-fortified soils. Those results are shown in Figure 54. Although the slopes are less steep (about 8°) than in the other study, water not absorbed into the soil during a rain does run off. Thus, the compost-treated plots have more water available for plant growth. Research is being continued to determine whether this results in greater yields or better quality of grapes and wine.

Compost Utilization in Basic Agriculture—Braunschweig. In all uses of compost today, the

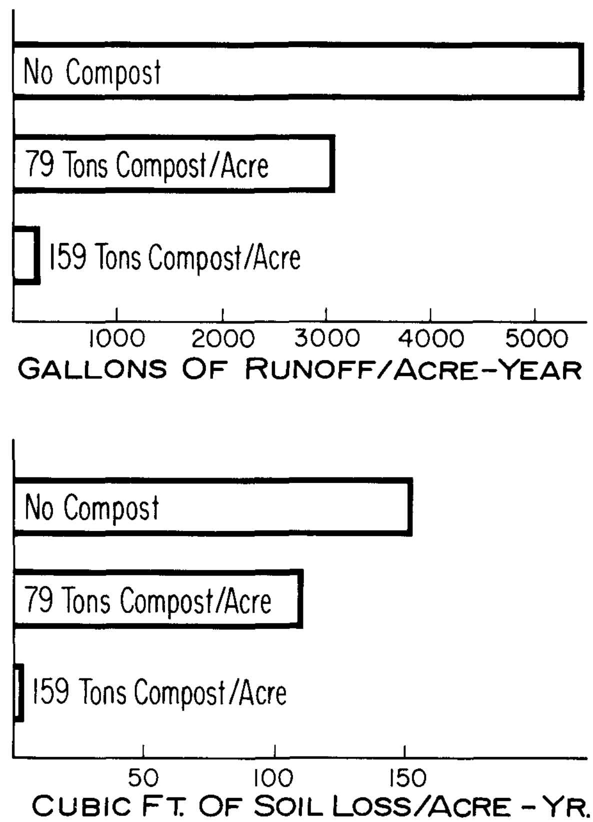

FIGURE 53. Average water and soil loss from 30.1° vineyard slopes at Bad Kreuznach, Germany.

important factor is the organic matter in the compost, not the nutrient content. Before chemical fertilizers became generally available, nutrient content was important in manures, composts, and other organic materials used by farmers. But, as indicated earlier, the nutrient content is very low (typically 0.5 percent nitrogen, 0.4 percent phosphorus, and 0.2 percent potassium). At today's prices of 8 to 10 cents per pound for chemical nitrogen, 15 to 16 cents for phosphorus, and 6 to 7 cents for potassium, it can be seen that 1 ton of compost has rather negligible nutrient value. When chemical fertilizers first became generally available, soil research compared chemicals with organics, and the latter almost invariably came out second best. Today, the research has taken on more sophistication. Research is being conducted on organics *plus* chemicals, the intention being to obtain maximum yield along with maintenance and improvement of the land.

The "Forschungsanstalt für Landwirtschaft" (Research Station for Agriculture) of the Fed-

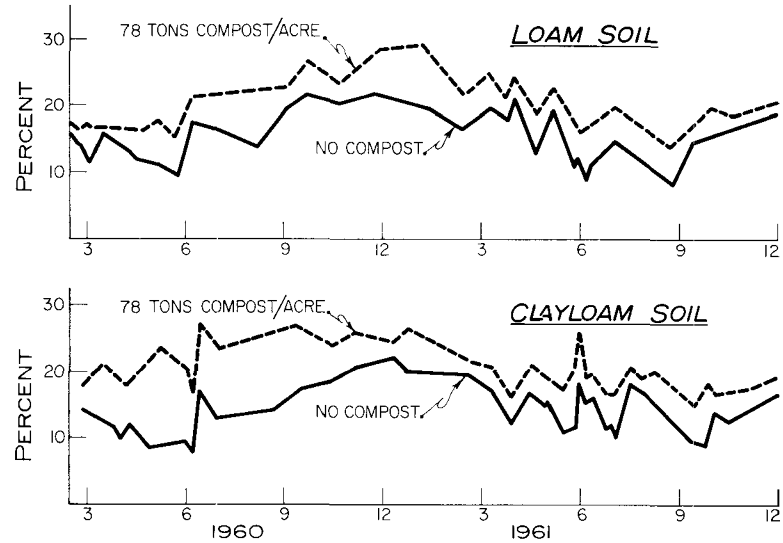

FIGURE 54. Soil moisture regime on two vineyard soils at Bad Kreuznach, Germany.

eral Republic of Germany, at Braunschweig-Volkenrode, is somewhat equivalent to the U.S. Department of Agriculture's Beltsville, Md., Experiment Station. In World War II the former was a secret research station for the German Luftwaffe. Most of the land then was in a 60-to-100-year-old mixed forest, making it possible to hide an elaborate research complex. After the war nearly half the forest was cut down for timber and firewood. (This is in contrast to the usual German practice of selective harvesting.) The adaptability of the buildings for further research, plus the clearing of virgin land, was the basis for founding the Agricultural Research Station at this location.

One of the 12 research groups at the Research Station is the Institute for Humus Management. Research at that Institute is aimed at maintaining and improving both crop yield and soil quality through husbanding the soil organic matter. Much of the research of this Institute has dealt with compost utilization. In recent years this has been conducted by Dr. C. Tietjen. One of his important research contributions deserves summary here.

Composts or manures added to the soil undergo biological stabilization. Byproducts of this microbial activity include humic acids and humus materials. These latter are quite effective in improving the physical characteristics of soils, through improving the soil's structural "fabric." One can ask whether the applied organic matter should be well rotted or should be relatively fresh. The argument for using well rotted materials is that one incorporates a material much like humus itself and so the soil microlife is minimally disturbed—thus crop yields are not so likely to be depressed in the year of application. The argument for applying fresh material is that the farmer supplies more microbial "food," effecting a greater degree of soil improvement.

One of Dr. Tietjen's long-term compost utilization studies is concerned with this particular question. Compost directly from the Bad Kreunzach drum (5 days of rotation) is being compared with compost that has "cured" for 9 months after being removed from the drum. (The field plots are on healthlike sandy soil at Braunschweig; the compost is shipped from Bad Kreuznach.) Table 2 lists the composition of the composts used in the study.

TABLE 2. COMPOSITION OF COMPOST USED IN THE BRAUNSCHWEIG STUDY ON AGE OF COMPOST

[In percent]

	Fresh compost	Cured compost
Organic content.........	28.4	19.1
Nitrogen.................	.48	.46
Phosphorus (as P_2O_5)......	.29	.31
Potassium (as K_2O)........	.41	.45
Calcium (as CaO)..........	2.91	3.78
Magnesium (as MgO).	.90	1.05

Table 3. Effect of fresh and cured compost on yields*

	Year of application (potatoes)		2d year (rye)		3d year (oats)	
	Fresh	Cured	Fresh	Cured	Fresh	Cured
No nitrogen:						
+no P_2O_5	97	117	134	117	122	111
+adequate P_2O_5	98	117	145	128	131	123
Medium nitrogen:						
+no P_2O_5	95	104	118	111	113	111
+adequate P_2O_5	95	99	127	121	118	113
High nitrogen:						
+no P_2O_5	93	103	112	107	111	108
+adequate P_2O_5	99	100	112	108	114	107

*Yields in each treatment are expressed as percent relative to equivalently fertilized [with chemical fertilizer] but noncomposted plots

These two composts were applied to the individual plots at 100 metric tons per hectare (89 tons per acre) at the beginning of the experiment. At the end of the first 3-year rotation, compost was applied again—at 90 metric tons per hectare (80 tons per acre)—and a like 80 tons per acre was applied again between the second and third 3-year rotations. Chemical fertilizers were applied each year: sufficient potassium to all plots; sufficient phosphorus to half of each plot and none to the other half; and nitrogen at three rates—zero, medium, and high. (The effect of nitrogen is twofold: It serves as a nutrient to the plant being grown; and it fertilizes the soil microorganisms attacking the added compost.) The crop rotation was potatoes, rye, and oats. The soil was a silty sand with a pH of 5.8. Figure 55 is a photograph of the plots at the ninth year harvest (of oats).

Table 3 presents the averaged yield ratios (combining potato yields of years 1, 4, and 7; rye yields of years 2, 5, and 8; and oat yields of years 3, 6, and 9.) The fresh compost depressed the yield of the first crop (potatoes), whereas the cured compost effected a slight yield increase. Yields in the second and third year were higher for both kinds of compost than for equivalently fertilized but noncomposted plots, with fresh compost superior to cured compost in yields produced. By taking the average of the averages, one can say that cured compost increased the yield relative to equivalently chemically fertilized but noncomposted plots by 11.1 percent, and fresh compost increased the yield by 11.7 percent. However, the plots well fertilized with chemicals but without compost outproduced poorly fertilized but composted plots. Thus, the farmer will generally prefer to buy and spread more chemical fertilizer rather than buy compost.

The nutrient levels of the harvested crops were measured each year, and the data are averaged in table 4. In the first year, cured compost was superior to the fresh compost in increasing the nutrient content of the crop, but in the second and third years the fresh compost was definitely superior.

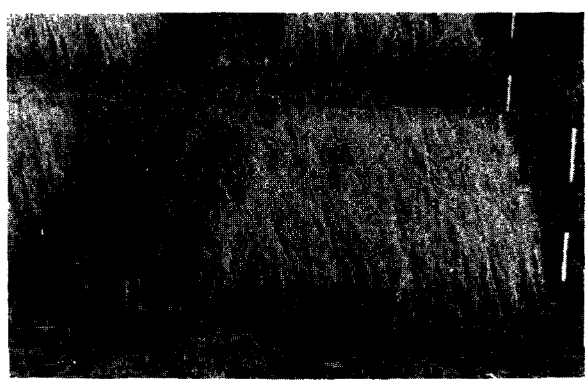

Figure 55. Dr. C. Tietjen's compost utilization experiment at harvest time.

TABLE 4. EFFECT OF FRESH AND CURED COMPOST ON NUTRIENT LEVELS OF CROPS*

Nutrient in harvested crop	Year of application (potatoes)		2d year (rye)		3d year (oats)	
	Fresh	Cured	Fresh	Cured	Fresh	Cured
Nitrogen	101	121	128	119	132	113
Phosphorus (P_2O_5)	101	103	138	120	129	119
Potassium (K_2O)	104	111	127	116	135	117

*Yields are percentages relative to noncomposted but otherwise equivalently fertilized plots.

Responses of the soil to the compost application and crop rotation were measured in the seventh and eighth years, and the data are averaged and presented in table 5. As can be seen, compost additions increased the soil organic content and pH. This improved the physical structure of the soil and may well account for the better yields of composted plots than of equivalently chemically fertilized but noncomposted plots.

TABLE 5. SOIL CHARACTERISTICS IN THE COMPOST RIPENESS EXPERIMENT

	No compost	Fresh compost	Cured compost
Organic carbon (mg/100g)	1950	2300	2280
Total nitrogen (mg/100g)	124	153	145
Available P_2O_5 (mg/100g)	21	31	31
Available K_2O (mg/100g)	17	30	29
Available Mg (mg/100g)	8	13	14
pH	5.9	6.8	6.5

In this experiment, as in others that Dr. Tietjen has conducted, it is obvious that compost does help the soil itself and does improve yields over those of equivalently fertilized (with chemicals) but noncomposted plots. The real limitation is that high applications of chemical fertilizers alone give a higher crop yield than medium levels of chemicals plus compost. Thus, the farmer is tempted to spend his available soil-improvement money exclusively on chemical fertilizers rather than dividing it between compost and chemical fertilizers.

Dr. Tietjen is trying to measure the long-term effects of cropping with and without composts and other organic matter. The argument can be advanced that although chemical fertilizers may be more profitable for the short-term, soil organic maintenance through compost additions may be in order for the long term (50–100–200 years into the future). This research work is not yet in excerptable form, and therefore cannot be reported here.

Dr. Tietjen has summaried the present situation well. Reporting at the 1963 National Conference on Solid Waste Research,* he made the following pertinent summary:

> Viticulture, fruit-culture, and horticulture are special branches of land use, with special fertilization and cultivation requirements. They generally do not have sources of organic matter as a part of the enterprise. It is different in basic agriculture—in the production of small grains, corn, potatoes, sugar beets, and other crops. In most cases here a supply of organic matter can be found on the farm, such as stable manure on mixed farms, crop residues, green manures, and most important, a crop rotation that benefits the soil. Where specialty farmers are under economic pressure to produce crops without the possibility of providing for their own humus husbandry, refuse compost can be considered an available substitute resource.

*Tietjen, C. Conservation and field testing of compost. Utilization of composts in Europe. In *Proceedings, National Conference of Solid Waste Research,* Dec. 1963. Special Report No. 29. Chicago, American Public Works Association. p. 175–186.

The Potential for Composting and Compost Utilization in the United States

The preceding sections have attempted to put composting and compost utilization into perspective. It appears to the author that there are no real technological barriers to making compost. It does appear, however, that the utilization of compost is limited. There are successes in luxury agriculture, as evidenced in vineyard, flower, and landscaping uses, but basic agriculture cannot be expected to absorb the material. Further, the concept of composting must be considered from the municipality's viewpoint. Most municipal officials recognize that it is not possible to make money from refuse. The most that can be expected, with regard to composting, is that the net cost to the city for refuse disposal by composting will be less, or no greater, than the costs of disposing of the garbage by landfilling or incineration, or a compensating value can be put on the factors of reduced rate of consumption of burial sites or reduced air pollution relative to incineration.

It does appear that in the United States there are three specific areas in which refuse processing and discharge through composting have potential: (1) Small amounts of compost can be marketed for luxury agriculture, in which case the overall economics—to the producing municipality and to the user—are favorable. (2) The finished compost has value, but the economics—for the producer or for the user—must be related to intangible values. (3) The finished compost is either not valuable or only marginally so, but the overall economics are nonetheless favorable.

Condition 1: Compost for Luxury Agriculture. The concept of using compost in luxury agriculture has been adequately discussed in preceding portions of this report. The success in Holland is due to an emphasis in specialty and luxury crop agriculture, and an aggressive and dynamic sales organization. The United States, with its high standard of living, also supports a significant specialty agriculture. No truly dynamic and efficient marketing organization for compost, however, is yet in existence. If it were, some small percentage of this nation's domestic refuse could probably be utilized at an economic advantage to both producer and user. The percentage so handled would unquestionably be less than Holland's 17 percent but could certainly be as great as Germany's 0.5 of 1 percent. Possibly 1 percent is a realistic figure; this would amount to beneficial, economic conversion of the wastes from 2 million people.

Locations where composting operations could be successful would have to be selected with extreme care. A market analysis would have to be the first step; transport costs are so great that the compost must be marketable in the local area. Three examples of this market sensitivity are pertinent. For a number of years the Metropolitan Waste Conversion Corp. at Largo, Fla., was successful in making and selling a limited amount of domestic compost. In 1966

St. Petersburg, only 15 miles from Largo, installed a 105-ton-per-day refuse conversion plant which was able to make 50 to 60 tons of compost per day. This quantity completely saturated the market, so that Metropolitan Waste Conversion has ceased operations at Largo. And St. Petersburg has yet to solve its marketing problem.

In 1965 to 1966, Houston, Tex., let contracts for two composting plants. It seems likely that there will be serious marketing problems when and if both plants get into full operation.

One might think Los Angeles would be a good area for composting because of all the gardening and outdoor living. But refuse compost must compete there with dried and composted dairy manure—higher in nutrients and with other quality characteristics as good or better. And the manure sells for one-half to two-thirds cent per pound in bags at retail garden stores and supermarkets; compost from domestic refuse just cannot compete.

There may well be other markets, as yet untapped, for compost. With further processing, compost could be pelletized to serve as an organic carrier for chemical fertilizer. In Holland some compost is sold as a litter material for livestock housing and as a mulch for packing bulbs. There are antibiotics and vitamins in compost that might be recovered. But even with these markets it appears that the quantity of compost that could be beneficially utilized is small—the 1 percent suggested earlier.

Condition 2: Compost Has Value and Economics Do Not Control. After the above emphasis on a proper economic approach, one might question the idea of compost production and utilization under a less-than-favorable economic situation. But man neither lives by bread alone nor thinks in tangibles alone. The intangible of enviromental management, if not environmental improvement, can and should be a powerful force. Compost production and utilization might be justified on the basis of lesser insult to the environment. Compost production and utilization might be justified on the basis of improvement of our already despoiled resources.

Hypothetical but specific examples of the potential of composting in this area are numerous. A city might be investigating incineration and composting. The net cost of composting might be greater than that of incineration, but climatic or geographic factors might be such that the extra air pollution from incineration would be undesirable. Composting might thus be a better choice, and the additional cost of composting would be recognized, acknowledged, and paid.

The noneconomic benefit of composting within the city's wastes management program can be cooperative rather than competitive. It is generally acknowledged that landfilling is the least expensive waste disposal method. In fact. landfilling is always a necessary part of a waste disposal program. Incinerator ash must be buried. The uncompostable plastics, glass, and other material must be buried. The city's building and demolition wastes must also be buried. Yet even sanitary landfilling has disadvantages—excessive land use and possible water pollution problems. Landfilling can not be abandoned because it may have these faults. Rather, the landfilling practice should be improved to eliminate such faults. Composting can assist in this. Diversion of compost to other uses, of course, reduces the volume of material going into the fill. And even if refuse is made into rough compost and the compost put into the landfill (not sold), there is a volume reduction. Further, filling a landfill with uncompostable residues—or the compost itself—would be more sanitary and less likely to cause water pollution than landfilling with raw refuse.

There is a second way in which composting can aid the landfilling operation. Sanitary landfills are usually used until they fill a depression or until they run out of cover dirt. Yet an above-grade sanitary landfill to build a hill or mountain is very desirable for future recreational use. One can visualize a percentage of a city's garbage being composted to produce cover material for burying the rest of the refuse. In this way a rubbish mountain, covered with trees and grass growing on compost, would benefit future inhabitants of the city.

There is a very important area where compost utilization can be beneficial although the economics are not favorable on a basis of immediate or tangible returns. This area is the reclamation of despoiled lands. Strip mining for coal, iron, gold, and other resources, has already defaced 800,000 acres of land in the United States. It was not economic during the mining, and it is not economic today, to repair these disfigurations of our landscape. Yet we are embarked upon a program of national beautification, and as a matter of policy we intend to reclaim these blighted spots. Organic matter is definitely needed on some of the mine-spoil and debris piles, and compost from municipal waste is a logical source of this organic matter. Some research is planned at the Joint U.S. Public Health Service–Tennessee Valley Authority Composting Project, Johnson City, Tenn., to study reclamation of sites blighted by strip mines. Worthwhile in this endeavor will be some of the research at Blaubeuren, Germany, and Dr. Kick's work at the University of Bonn, Germany.

In the future, as recreational areas for the expanding population become more valuable, it may become feasible to reclaim naturally barren or infertile areas. Organic matter is a first need of such lands, and, again, compost is an appropriate material. A specific example of a possible area of use is in the reforestation of wastelands of shallow soil that are marginally watered. Trees will often grow on north slopes, where drying out of the soil is less severe, while south slopes are dry and barren. As shown earlier, compost improves the soil's water-holding capacity. It might well be that compost incorporation, along with forest management, could reclaim these south slopes.

All of these ideas are desirable and beneficial, but hardly economic. At least, it is hard to justify their worth through straightforward economic analysis. The intangible of future beauty does not have a generally agreed upon present dollar value. However, in the coming years some of this land reclamation and beautification will occur and will be able to utilize compost. In honesty, probably less than 1 or 2 percent of the nation's refuse generation would be channeled into this disposal—but it would certainly be a desirable avenue.

Condition 3: Compost—Nonbeneficial but Economic. There is a third and last concept under which composting and compost utilization can proceed, and this has greater potential than either of the choices discussed above. It is a middle ground, between using compost at 15 to 50 tons per acre-year for crop production or land improvement, and using the land as a refuse burial site. (About 800 tons of refuse will raise the elevation of 1 acre of landfill site by 1 foot.) Conceive of the application of 100, 200, or 300 tons of rough-quality compost per acre per year, year after year. The land would be an acceptor, degrader, and stabilizer of the waste; crop production would probably not occur; but neither would the land be lost to a future use.

The concept is similar to that involving the use of land for sewage irrigation. A community decides it cannot afford a sophisticated sewage treatment plant, and so it makes a parcel of land into a sewage spreading ground. The land and the sewage are not used for crop production, but only to get rid of the sewage. Hopefully, after a few years the community will build a sewage treatment plant, and then the land can again be used for agriculture, or for subdivision, or recreation, or something else.

This philosophy and system is equally appropriate for solid waste management. Put bluntly, it would be insulting Mother Earth without quite violating her. Each year, as much rough compost—or perhaps just ground refuse—would be incorporated into the soil as could be assimilated. When the land is needed for another purpose, the compost application would be stopped, and the land would recover. This concept of compost utilization might be likened to a biological incinerator. The applied organic matter would be burned and consumed by the soil microbiological activity. The operating cost of this biological incinerator will probably be higher than running a thermal one, but the capital cost, and thus the amortized cost, should be much lower. For many cities this scheme might well be preferred over conventional incineration. As a hypothetical example, if a soil could take 100 tons of rough compost per acre per year, produced from 200 tons of domestic refuse, this would be a land requirement of 1 acre per 500 people. This is even less land than is required for sewage lagoons.

One of the beauties of the system is its possible political expediency. A rose by any other name is still a rose, and possibly garbage burial as suggested here is still garbage burial, but if it is called and considered "organic dressing of the topsoil," it might be accepted by a community that adamantly opposes the conventional sanitary landfill.

Needed research on the soil science, the engineering practicability, and the economic feasibility have not yet been worked out, but is beginning (at the University of California under USPHS Research Grant SW 00003). The research teams are trying to determine the maximum assimilative capacity of soil for organic matter, and whether the form is important—as raw ground refuse, as fresh compost, or as cured compost. The best way to apply the waste must be determined—as a top dressing, mixed into the top few inches of soil, or thoroughly incorporated into the soil. The economics of tillage, pH control, frequency of application, and similar variables must all be worked out.

At this stage it is impossible to estimate what percentage of the nation's refuse might be so managed. It would appear that this system might have merit for communities with populations between 10,000 and 100,000. There are 1,760 such communities in the United States, with a total population of nearly 50 million, or 25 percent of the nation's population. If this method of refuse disposal were appropriate for even one-third of these communities, it would be a substantial avenue of waste disposal.

Recommendations for U.S. Composting Research

With the passage, in 1965, of the Solid Waste Disposal Act by the Congress and the President, this nation is embarked upon a comprehensive solid waste management program. One part of that program is support for research and development—to find answers today for tomorrow's problems. This research in solid wastes embraces all areas of management—collection, storage, transport, processing, and discharge. A goodly part of the research presently sponsored by the U.S. Department of Health, Education, and Welfare involves aspects of composting. Even so, there appears to be room for additional research effort in the composting field. Such additional research would complement the presently supported research.

Marketing Research. The need for a market analysis prior to construction of any new composting plant was suggested in the preceding section. But also much in order is a more comprehensive marketing research study for the general proposition of composting. It should be determined what the total extent of the market for compost is, what qualities of compost make for salability, what the going price could be, and what the competition would be (from manures, peat moss, and sewage sludge). Such a market survey could determine whether compost really has a future for luxury and specialized agriculture, or whether composting advocates just do not have the facts straight.

This survey might be expanded to cover compost use possibilities suggested in the second part of the preceding section—compost for land reclamation. Transport costs, compost quality requirements, and sources of financing for the use of the compost would all be a part of such a study. It might even be possible to investigate whether advertising and a "Madison Avenue Approach" could appropriately be applied to a Compost Utilization program.

It seems unlikely that academic researchers would be interested in—or capable of—conducting this type of market survey. Rather, such a study might best be contracted out either to strictly commercial companies or to nonprofit research organizations.

Composting Cost Studies. Related to the marketing of compost is the cost of preparing the compost for market. Composting was first conceived of as benefiting basic agriculture, and compost of rough or poor quality was deemed adequate. Over the years this market has been unsatisfactory, so quality has been continually upgraded by extra sieving, crushing, grinding, ballistic separation, incorporation of fillers and chemicals, pelletizing, and the like. Much research on the biological processes of composting is already being supported. But it is the mechanical processes and the simple materials-handling problems that, more than anything else, contribute to the cost of composting. It seems appropriate that a cost-engineering appraisal be made of the mechanics of composting.

What is the comparative cost of grinding refuse before versus grinding after composting? What is the cost of sieving compared to ballistic separation? These and other cost-comparatives studies should lead to a more economical compost manufacturing process, and to a compost tailored to specific markets. This could be grant-supported research if some university academician were interested, or it could be contract research. This information, plus the marketing research, would do a great deal toward putting composting into place and into proper perspective.

Wasteland Reclamation Research. It was previously stated that minelands and other wastelands can be an acceptor of compost. Research by Drs. Kick and Spohn in Germany was discussed, and the intent of the PHS and TVA personnel at the Johnson City composting plant to engage in this was mentioned. This is extremely important work, and should be pursued diligently and energetically along two lines—the technology of land reclamation, and the engineering economics. It would be very desirable if a team of a soil scientist, an agricultural engineer, and an economist could become active on this project. The soil scientist could design and test the various experiments and programs of strip mine reclamation in the Appalachian area near Johnson City. The agricultural engineer could assist in the application equipment design and procedure, and the economist could interpret the financial conditions. Within 10 years there could be developed a real backlog of knowledge and understanding of the problem, and of methods of solution.

This work could be done by academicians from nearby universities (University of Tennessee and University of Kentucky) working with the PHS and TVA personnel at Johnson City. If the academicians are not particularly interested, however, the work should be pursued directly with government research scientists.

Pesticide Degradation in Organically Enriched Soils. Ever since Rachel Carson wrote the book *Silent Spring,* the problem of pesticide residues has been generally acknowledged. It has been indicated by some initial research (by Dr. Strauch and Dr. Farkasdi at the University of Giesson, Germany) that pesticide residues are degraded more quickly and more completely in compost-enriched soils than in normal soils. This is a most significant hypothesis, and one worthy of immediate and dedicated research. If it is true, it could be an important reason for using compost in basic agriculture. And, more importantly, it would assist in reducing the pollution of our environment from the pesticides being used in ever-increasing amounts.

This appears to be research that could well be conducted at universities with USPHS research grant monies. It would require a team approach—of soil microbiologists and agricultural toxicologists or chemists. This research should be fundamentals oriented, aimed at learning the process and metabolism of pesticide breakdown. Application of the findings would be a second step, dependent upon the basic research developed by the fundamentals study.

Pathogen Survival Research. As previously reported, Dr. Strauch at the University of Giessen, Germany, ran comprehensive studies on pathogen survival during the composting process. This is so important to the future of composting in the United States that supplementary work might well be conducted here. This could probably best be pursued at the Joint U.S. Public Health Service-Tennessee Valley Authority Composting Project, Johnson City, Tenn. It would also be extremely desirable if Dr. Strauch could be hired for a year to consult with U.S. scientists in this study.

Also worthy of research effort is a second aspect of microorganism activity in compost. The composting process is a biological degradations fungi and bacteria attack and degrade the raw waste and convert it into compost. As the composting is completed, many of these microorganisms sporulate so as to await a more optimum food supply later. The compost is used on the land, perhaps on some specialty food crops. Does the food become contaminated with the compost-processing microorganisms? Does canning, pickling, or the other food-processing operations kill the spores? Or could these spores become active again and cause food spoilage and food poisoning problems? Research on compost utilization and food spoilage is thus an appropriate area of academic research. It could well be supported by U.S. Department of Health, Education, and Welfare grant monies.

The Land as an Acceptor of Wastes. Really, nothing more needs to be said here about this research proposal, since it has been discussed in the preceding section (p. 33 to 36). This does seem to be the greatest potential for compost or raw refuse discharge in the future. Research on it is already beginning at the University of California, under USPHS Project SW–00003.

Conclusions

Composting has frequently been advocated and considered as a method of solid waste management in the United States. The key to success or failure of American composting has been and will continue to be related to whether and how the finished compost can be utilized or discharged.

Today substantial quantities of compost are being produced and utilized in Europe. A study and analysis of compost utilization there should be helpful in appraising the potential for success of future American composting operations. To this end, a study of compost utilization and compost utilization research in Germany, Switzerland, and Holland was undertaken in 1966 and 1967.

The results of that study, including visits to 14 composting plants and various research organizations, led to the following conclusions:

1. Compost in Europe primarily has usefulness in intensive, luxury-type agriculture. It is used in flower and fresh vegetable culture where frequent tillage tends to destroy soil fabric, and on hillside vineyards where erosion control is necessary.

2. Compost plus chemical fertilizers can be used in general agriculture (cereal and field crops) but maximum yields at minimum cost are obtained with chemical fertilizers alone, and soil tilth is adequately maintained with normal crop rotations.

3. Reclamation of strip mined areas with compost is being actively researched and offers considerable promise.

4. Public health considerations regarding compost production have been well researched by scientists at the University of Giessen, Germany.

5. Compost utilization in the United States appears to have limited potential, and such utilization is likely along three routes:

a. Commerical, economic utilization of compost in the conventional manner—for intensive, luxury-type agriculture. Perhaps 1 percent of the nations' domestic refuse might be utilized in such a manner.

b. Utilization of low-grade, economically produced compost for land reclamation and cover material for sanitary landfills. Perhaps 1 to 2 percent of the nation's domestic refuse might eventually be so channeled.

c. Compost (or ground refuse) spreading and incorporation onto certain lands, using the land plus the composting process to stabilize organic wastes, rather than using compost to benefit the land. Composting would be a type of biological incineration with the land being the incinerator. Such a scheme could be sanitary, feasible, and perhaps economic for small towns and cities (to perhaps 100,000 in population). Perhaps 5 to 8 percent of the nation's domestic refuse might eventually be so managed.

6. Although considerable U.S. Public Health

Service-sponsored research on composting is already in progress, additional studies are appropriate in the areas of compost marketing, composting unit operations costs, wastelands reclamation, pesticides breakdown in organically rich (compost-fortified) soils, pathogenicity in the actual utilization of compost, and land as an acceptor of wastes.

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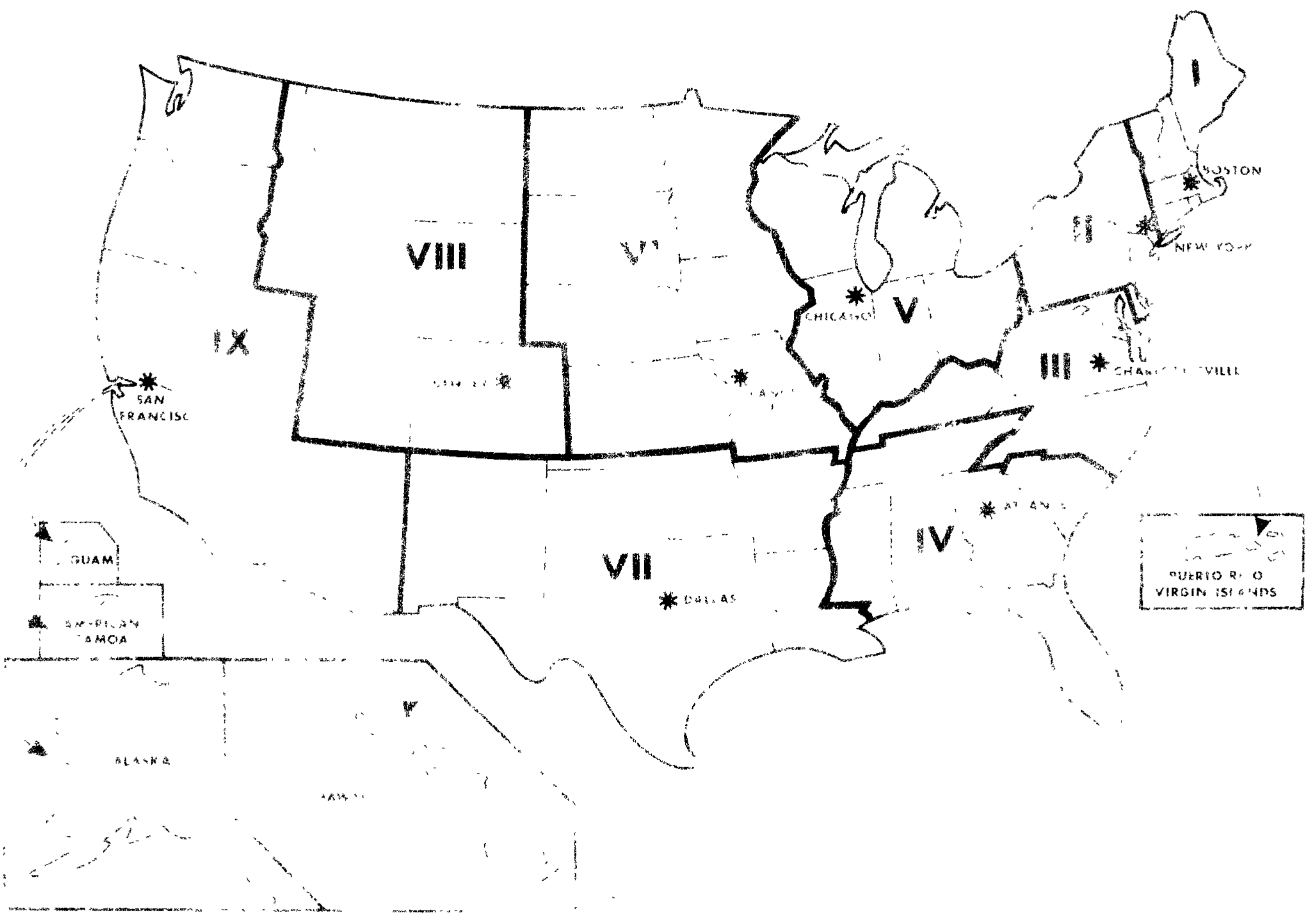

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