Brianna Bergen - Comments and documents for Nursery Products WDRs 4

From: "D. Norman Diaz" <[redacted]
To: Brianna Bergen <[redacted]
Date: 11/23/2009 2:29 PM
Subject: Comments and documents for Nursery Products WDRs 4
Attachments: 071221 lost hills liberty.pdf; 080706 Banning plan.pdf; 080707 rialto e-fuel.pdf; 080814 coltonThermoEnergy, STORS.pdf; ABT Odor Controàeport F[1].pdf; Beltsville Aerated Static Pile Composting-1.pdf; Compost operation on hold until renovations done | CourierPostOnline.com | Courier-Post.pdf; SlurryCarbOverview.pdf

Ms Bergen
Please consider these comments and documents for your WDRs for Nursery Products LLC or any other Nursery Products or sewage sludge permits:
A few enclosed cost effective sludge alternatives being started in Southern California shown here in these articles. If it is cost effective to build a $200 million dollar facility in Banning for profit, then how can it be not cost effective in Hinkley? Where is the $200 million Banning is spending on its facility compared with no cost to Nursery Products in Hinkley? Why is Banning's local water given stronger safety measures over Hinkley's?

thanks

Norman

D. Norman Diaz
[redacted]

SLUDGE POWER

Local company aims to capitalize on using sewage to generate electricity

BY STACEY SHEPARD, Californian staff writer
e-mail: sshepard@bakersfield.com | Thursday, Dec 20 2007 10:20 PM

Last Updated: Friday, Dec 21 2007 8:02 AM

That stuff you flush down the toilet may someday provide power to your home. The state's largest sewage sludge composter, located near Lost Hills, plans to build a renewable energy plant that burns treated human waste and other organic material to make electricity.

PHOTOS:

Photo by John Harte

Pat McCarthy at the Liberty Recycling Inc. facility in Lost Hills.

Photo by John Harte

Operations manager Gary Bruggeman and company president Pat McCarthy of Liberty Recycling Inc. pose in Lost Hills.

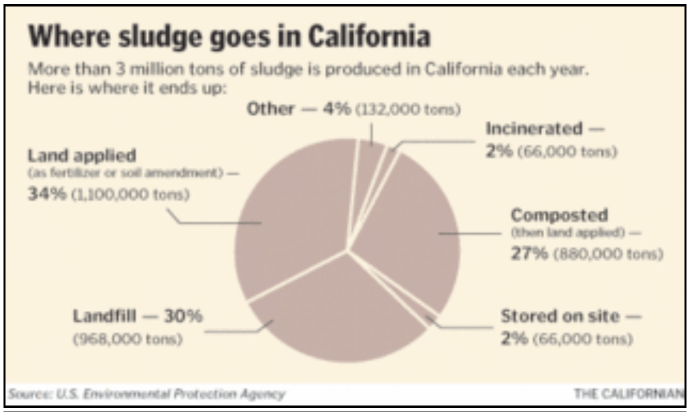
Owners of Liberty Composting, formerly San Joaquin Composting, already have a contract to sell 20 megawatts of electricity from the planned $64 million facility to Pacific Gas and Electric. Construction of the plant, called Liberty V, is slated to start in three years.

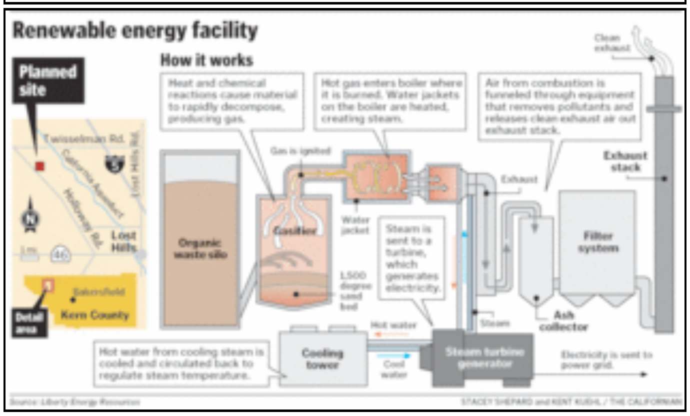
The move is part of the company's desire to find a better use for sludge in the face of stricter air pollution regulations and public concern about sludge disposal, said Patrick McCarthy, president of McCarthy Family Farms, which owns Liberty Composting.

"Five years ago, we started talking and said there's got to be a better alternative to composting," McCarthy said. "Our idea is to take these problematic organic waste streams and use them for their highest and best use in the most environmentally friendly manner, and in doing so, generate renewable energy."

Liberty Composting receives up to 780,000 tons of organic waste annually. The majority is sewage sludge from 48 communities from Los Angeles to Santa Cruz. California produces about 3 million tons of sludge a year. About one-third is directly applied to the land, another third

GRAPHICS:





goes into landfills and the rest is composted.

About 90 percent of the finished compost from Liberty Composting is used at McCarthy Family Farms' Liberty Ranch in Kings County.

The Liberty V plant will use a process called gasification, whereby sludge and other organic waste is heated at temperatures of more than 1,500 degrees in a low-oxygen environment.

The heat drives gases off the waste and into a chamber where injected oxygen causes the gases to ignite. The combustion heats water and the resulting steam spins a turbine, creating electricity.

Some butane is required for initial start, McCarthy said, but afterward the facility can sustain operation without an additional fuel source.

'More responsible approach'

The project will require a full environmental review but the company is touting it as a sound solution to several environmental concerns.

Air pollution will be drastically reduced because the power plant will have the most up-to-date pollution controls and airtight storage silos, McCarthy said. Farmland would not be used as the final resting place for sludge. And the facility would generate renewable energy.

Because of that, the project has received a warm welcome so far from air regulators, sludge critics and public utilities.

"They're moving to a more responsible approach," said Maureen Reilly, a Canada-based sludge watchdog who's been involved in Kern County sludge issues. "They shopped the marketplace and looked at what more can you do with sludge. I think that makes sense."

The switch from composting to a gasification plant has the potential to remove more than 80 percent of the gases and dust produced by the company's current composting practices, said Lucinda Roth, senior air quality specialist with the San Joaquin Valley Air Pollution Control District.

"Without seeing the engineering plans, it's hard to say but most likely they will get more than 80 percent," Roth said.

McCarthy said plans reviewed by air regulators show a potential air pollution reduction as high as 95 percent. In addition, he said, pollution will go down from a reduction in trucks hauling finished compost off site. Trucks will still be needed to transport the ash left over from the burning process to factories that make Portland cement. The number of trucks will go down, though, because one truckload of ash is equivalent to about 10 trucks of compost, McCarthy said.

Some composting continues

A limited amount of composting will likely continue after the power plant is built, McCarthy said, but the amount of sludge and other waste coming into the facility will not exceed the current amount.

McCarthy Family Farms, a four-generation, family-owned farming and agriculture land development operation, got into the composting business more than a decade ago when it stopped spreading sludge directly onto its farmland out of the belief that composting was a more environmentally friendly approach.

Five years ago, the company found itself again re-evaluating its practice.

"We set out saying, what can we do to handle this material so it would be more acceptable and people could benefit from its use," McCarthy said.

After several trips to Europe to see how sludge was being handled there, the company settled on building a gasification plant.

Several gasification facilities have been proposed in California and surrounding states but none has been built yet, according to the U.S. Environmental Protection Agency.

"With more of an emphasis on renewable energy ... there's going to be much more interest in doing this," said Ben Machol, senior energy adviser with EPA.

Market for similar plants

A recent California state mandate that requires public utilities to obtain 20 percent of their power from renewable sources by 2010 has spurred market growth for new forms of renewable energy, McCarthy said.

In addition to the Lost Hills plant, Liberty plans to build similar power plants in Banning and Niland in Southern California and in Ontario, Canada.

"We're very excited about the potential long-term environmental benefits," said Jim Earhart, director of Banning's municipally owned electric utility. The utility has contracted to receive 15 megawatts from a Liberty plant to be built there.

During winter months and at nighttime, the facility is expected to provide 100 percent of the power to the city of 30,000 residents.

While the project has been praised as a better alternative to sludge handling, questions remain about the practice of having other cities' sewage trucked into Kern County.

"Bringing such a project to Kern County doesn't make environmental sense," said state Sen. Dean Florez, D-Shafter. "To me, it sounds like a great project for Los Angeles County."

McCarthy said he understands people don't like that Kern County is the final stop for other cities' waste.

"At the same time, if we can turn that material into something useful, like fuel, I'd feel a little bit better about it," he said. "I think this is an important opportunity for (communities) that feel like they've been dumped on to turn this around into a positive thing."

Liberty receives up to 150,000 tons of sludge produced annually in the San Joaquin Valley, McCarthy said. For Liberty V to be economically viable, waste from outside the area is necessary.

New use

Name: Liberty V

Owner: Liberty Energy, a subsidiary of McCarthy Family Farms, which also owns Liberty Composting in Lost Hills, Liberty Ranch in Kings County, and Liberty Logistics, a Bakersfield-based sludge trucking company.

Location: Eight miles northwest of Lost Hills

Process: Burns organic waste in a controlled environment to create electricity

Capacity: 760,000 tons per year of organic waste (primarily sewage sludge but also grass clippings, processed food waste, orchard prunings and animal waste)

Production: 20 megawatts of electricity to be sold to Pacific Gas and Electric

Cost: $64 million

Timeline: Construction anticipated in 2011

BY THE NUMBERS

3.1 million: Tons of sewage sludge produced in California annually

1.1 million: Tons of sludge used as fertilizer (no composting)

880,000 tons: Tons of sludge composted

Source: Environmental Protection Agency

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News

Bio-solids plant is city's largest project ever

Rendering of the outside design of the $180 million bio-solids energy plant being proposed in southeast Banning, near the city's wastewater treatment plant. Trucks would unload sewage sludge inside the building.

A proposed $180 million bio-solid energy plant in Banning would be the largest commercial project in the city's history, generating as much as 45 percent of the city's electricity needs, providing many local jobs and contributing as much as $2 million a year in city tax revenues, the project's manager says.

Micheal Bracken, founder of Development Management Group, Inc., said in an interview that if the project gets the go-ahead by Banning's City Council in September, construction near the city's sewer treatment plant could begin by early next year, with two of three power-generation units operating by January 2011.

Bracken, who served on the Banning City Council in the late 1990s, is an investor in the sludge plant being developed by Liberty Energy Inc., of Bakersfield, on 20 acres near Smith Creek at the end of East Westward Avenue next to the city's wastewater treatment plant.

At full capacity, the state-of-the-art plant could turn treated sewage sludge and green waste from two million residents in cities from San Diego to Kern counties into electricity, which would be sold to the city's municipal utility at a discounted price.

"Liberty Energy is first, and foremost an environmental company," Bracken said. "Our vision is to create a safe renewable power generation facility in Banning that will provide renewable power to the community, create new job opportunities and generate about $180 million in economic investment that will also produce about $2 million of revenue annually for the city of Banning."

The plant would generate as much as 17 megawatts of electricity by burning sludge and green waste at 1,500 degrees, creating steam to run turbines. Banning could purchase all or as much of the plant's electricity as it needs.

While the project, called Liberty Energy XXIII, has inched along in planning for more than a year a report on its environmental impact on the area was just released and was the subject of a public "scoping" last Thursday at City Hall.

Bracken, an investor in the plant and its project manager, said said Liberty has spent more than $2.5 million on the project so far, including $500,000 on the environmental report, which, he said, Liberty had no control over.

Bracken said that the plant would have innovative equipment, some of it developed by Liberty Energy, to eliminate odor and reduce air pollution. He said the plant meets rigid air-quality standards of the South Coast Air Quality Management District, the toughest anti-pollution regulations in the world.

"The air out is cleaner than the air going in," Bracken said.

Bracken said he knows of no organized opposition to the bio-solids plant.

He acknowledged that critics usually focus on four factors: odor, traffic, noise and how the plant looks. He said Liberty Energy has been careful in addressing each concern. He said the plant would have an attractive appearance.

Bracken said that while the sludge will be hauled to the plant in large trucks, the trucks are sealed and there is no leakage. Once at the plant, a vacuum-like system ensures that none of the sludge or odor escapes outside during unloading. The trucks drive into the plant to unload.

"Odor is a common question," Bracken said. "On the bio-solid side, our trucks will enter reverse air chambers and the material is unloaded and the trucks are washed in a sealed system; the material then goes to a series of silos that are fully contained with charcoal type filters. Therefore, there is little to no odor, and certainly no odor" in the area from which people can see the plant. "Our plant is located right next to the wastewater treatment ponds," said Bracken. "Now that's odor."

Bracken said that many people don't realize that as many as 300 trucks loaded with sewage sludge from Los Angeles now pass through Banning every day on their way to a landfill in Arizona, where the sludge is dumped.

Bracken said that the plant includes three modular units, each handling about 25 trucks per day, for a total of 75 truckloads of sludge a day. Each truck hauls 20 tons of sludge for a total of about 1,500 tons of bio-solids a day.

Bracken said the sludge trucks would take the Hargrave Street exit off the I-10 south, turn east on Lincoln to Hathaway and then onto Westward to the entrance of the facility.

He contended that trucks would not pass residential areas, although three homes in an industrial zone are on the route.

He said Liberty Energy would spend as much as $2 million on lights and other improvements on Hargrave and along the route to improve traffic flow.

Bracken said that Banning's wastewater treatment plant and public utility would benefit from the project.

He said Liberty Energy would process the city's sludge at no cost, saving the city money it now spends to haul it away. In addition, he said Liberty would sell the city's public utility 15 magawatts of power at a price about five cents per kilowatt cheaper than what it costs on the open market.

In a serious blackout, Banning's utility could count on at least 15 megawatts of power, or about 45 percent of its average output, from the Liberty plant, Bracken said. The few megawatts of electricity not sold to Banning would power the plant, Bracken said.

The plant would be built in stages. Two of the three units would be finished and in operation by January 2011. The third unit would be finished in January 2013, Bracken said.

During construction, the project would generate about 100 jobs, and once completed, it would take as many as 75 employees to operate it, according to Bracken. The average hourly wage paid at the plant will be $20 an hour and the plant's payroll will amount to more than $3 million in wages and benefits.

He estimated that the project would pump $127 million into the Pass economy over 10 years. He said because the plant is proposed in redevelopment area, the city would pocket more than $12 million in property taxes over the same period.

Bracken also said that the plant would help Banning's utility meet goals of having electricity generated from renewable sources.

Bracken estimates that the project will have an overall economic impact of $127 million over the next decade on the Pass Area.

The plant would also process bio-mass or green waste in generating electricity. About 30 percent of the plant's capacity would be green waste, Bracken said. He said that while there will be some mounds of green waste at the plant they will have an emergency water sprinkler-like system or water cannons to moisten the material in case of a fire.

So far as winds blowing the bio-mass materials away, Bracken said, the mounds "will be kept low enough that that's not going to happen."

He said the green waste wouldn't smell. "This material is chipped to a 2 to 4 inch diameter and stored in the biomass yard," he said. "Because we don't use things that compost, the breakdown is much longer in nature. It's the breakdown that creates odor. So there are no odor issues there. SCAQMD will actually review our project and issue an odor control permit."

Liberty makes 80 percent of its revenue by charging cities to take their solid waste sludge. Bracken wouldn't say what cities the company is talking to about sending their sludge to Banning. He did say that the plant could bring in sludge from as far away as San Diego and Kern counties

The site is four-tenths of mile east of the end of Westward Avenue, according to Bracken, on land contiguous to Banning's treatment plant.

He said the plant will be highly regulated by local, state and federal agencies. The city, in issuing a conditional use permit for the project, will be part of oversight.

"The city, in their entitlement process, will consider a conditional use permit (CUP)," said Bracken. "Ultimately the permit will spell out that we are a pervasively regulated business, meaning that the city and a host of local, county, regional, state and federal agencies will have access at any time without notice to inspect our operations."

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EPA-600/8-80-022
May 1980

MANUAL FOR COMPOSTING SEWAGE SLUDGE BY THE BELTSVILLE AERATED-PILE METHOD

by

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FOREWORD

The U. S. Environmental Protection Agency was created because of increasing public and governmental concern about the dangers of pollution of air, water, and land to the health and welfare of the American people. Its personnel are charged with the responsibility of alleviating, correcting, and when possible preventing problems of that nature.

The U. S. Department of Agriculture is broadly concerned with all aspects of U. S. agriculture. Its personnel endeavor to facilitate the efforts of the U. S. farmer to supply food and fiber to populations at home and abroad, but always with the minimum practical hazard to the environment.

The work here reported was aimed at the furtherance of the purposes of both agencies. It originated from an urgent need of both large and small municipalities for better methods to dispose of ever-increasing amounts of sewage sludge. Composting offers a double-barreled solution to that problem. It not only disposes of sludge but also converts it into a product which is more aesthetically acceptable, safer from a health standpoint, and useful in many important practical applications as a soil amendment beneficial to the growth of plants. The present manual discloses details of the Beltsville Aerated Pile Method of Composting sewage sludge. Research conducted at Beltsville by USDA in cooperation with the Maryland Environmental Service with the support of EPA, has shown that composting is a cost-effective and environmentally acceptable alternative to such ultimate disposal methods as incineration, ocean dumping, and landfilling.

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Assistant Administrator for Research and Development
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PREFACE

In the early 1970's, the Blue Plains Wastewater Treatment Plant in Washington, D.C., serving seven jurisdictions, was producing about 300 wet tons (23% solids) of digested sludge per day. Construction for advanced wastewater treatment facilities displaced existing sludge storage. Disposing of the sludge by discharging it into the Potomac River or barging it for off-shore dumping into the Atlantic Ocean were both rejected as environmentally unacceptable. The consulting firm of Metcalf and Eddy, Inc. recommended sludge incineration as the best disposal system for Blue Plains. Until the incinerators could be constructed, the Maryland Environmental Service (MES), assumed the responsibility for disposing of the sludge by land application.

In 1971, the Biological Waste Management Laboratory at the U.S. Department of Agriculture's Beltsville Agricultural Research Center initiated research on land application of sludge in cooperation with MES and the Metropolitan Washington Council of Governments. Several methods were investigated, including trenching and landspreading. In 1972, at the request of MES and the Blue Plains participants, this Laboratory began research on composting of sewage sludge. By early 1973, a successful windrow method utilizing woodchips as a bulking and moisture-absorbing agent had been developed for composting digested sludge. During 1973 and 1974, the Beltsville facility windrow composted in excess of 50 wet tons of digested sludge each day (Figure 1).

By 1975, the Blue Plains Wastewater Treatment Plant had increased its capability for removal of solids from the wastewater. This resulted in the production of an additional 200 wet tons of undigested or raw sludge (a mixture of primary and activated secondary sludges), for a total output of about 500 wet tons of sludge per day. Meanwhile, digestion capacity remained at 300 tons per day.

Difficulties were encountered when the windrow method was applied to raw sludge, because of the greater level of malodors associated with this type of sludge. Moreover, raw sludge generally contains a higher level of pathogens and there was concern that some of these organisms might survive in the outer layers of the windrow, where temperatures would be lower. The need for disposal of the raw sludge resulted in the development of the composting process now referred to as the Beltsville Aerated Pile Composting Method described in this manual.

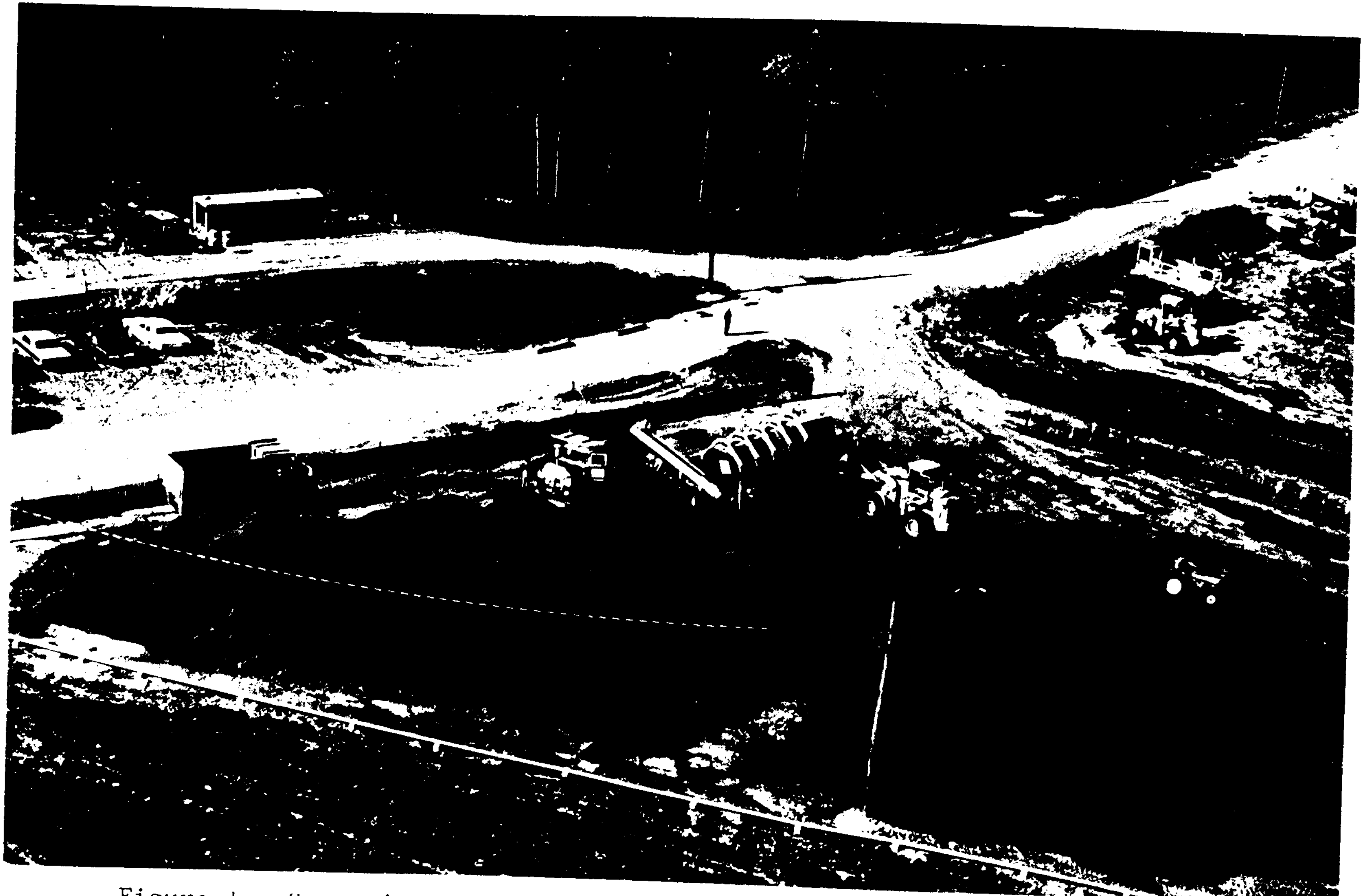

Figure 1. Screening woodchips from sewage sludge compost for recycling, Beltsville, 1973. Stock pile of screened compost in left foreground. Air-dried compost before screening in right foreground.

The Environmental Protection Agency has issued a deadline of 1981 or sooner to cities that are presently ocean dumping their sludge to cease using that method of disposal. This manual was developed for the assistance of those sewage authorities that must find acceptable new outlets for their sludge on short notice. The manual has been written during the early stages of research; improvements can be expected as development continues and communities adopt the process.

ABSTRACT

In producing clean water from sewage, wastewater treatment plants also produce sludge. Most of the commonly used methods to dispose of this material are now considered to be either environmentally unacceptable, wasteful of energy, or very expensive. To ease this situation, a relatively simple, rapid, and inexpensive sludge composting process has been developed at Beltsville. The method makes possible the conversion of undigested sludge into a composted product that is aesthetically acceptable and meets environmental standards. The material has demonstrated usefulness as a soil amendment stimulative to plant growth. If relatively simple control procedures are followed, the compost appears to be free of primary human pathogens because of the lethal effect of heat generated during the composting process on such organisms.

The new Beltsville composting procedure, detailed here in respect to both principles and practice, represents a major advance over previously known composting methods. It is adaptable to practical use in municipalities of widely varying size. In many situations its short startup time will allow its use as an emergency interim solution for sludge management. Key information is presented on the economics of the process, and on the marketing and use of the product as a soil conditioner to improve plant growth.

This report was submitted in partial fulfillment of Grant No. S803468 by the Maryland Environmental Service under sponsorship of the U.S. Environmental Protection Agency. Work was done under subcontract by the U.S. Department of Agriculture. This report covers the period July 1975 to December 1977, and work was completed as of June 1978.

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CONTENTS (continued)

CONTENTS (continued)

FIGURES

FIGURES (continued)

TABLES

CONVERSION FACTORS

Length	
1 inch	= 2.54 centimeters
1 foot	= 30.48 centimeters
Area	
1 square inch	= 6.45 square centimeters
1 square foot	= 0.0929 square meters
1 acre	= 0.405 hectares
Volume	
1 cubic inch	= 16.39 cubic centimeters
1 cubic foot	= 0.0283 cubic meters
1 cubic yard	= 0.765 cubic meters
1 gallon	= 3.79 liters
Weight	
1 pound	= 454 grams
1 ton	= 0.907 metric ton
Application rate	
1 pound per 1000 square feet	= 4.89 grams per square meter
1 ton per acre	= 2.24 metric tons per hectare
1 pound per acre	= 1.12 kilograms per hectare
Temperature	
F^{o}	$= 9/5\ C^{o} + 32$

ACKNOWLEDGEMENTS

We wish to acknowledge financial support from the Metropolitan Washington Council of Governments (COG), The Blue Plains Participants, and the Maryland Environmental Service (MES) throughout our research and development of sewage sludge composting at Beltsville.

The U.S. Environmental Protection Agency, Office of Research and Development, Cincinnati, Ohio, provided a 2-year grant (effective July 1, 1975) for research and development of process technology for composting municipal sewage sludges, and for investigating the use of sludge composts on land.

The U.S. Environmental Protection Agency, Region III, Philadelphia, Pennsylvania, provided a 2-year grant (effective December 1, 1975) for construction, improvements, and operations at the Beltsville Composting Facility.

We also acknowledge grants from the USEPA, Office of Research and Development, Cincinnati, Ohio, which have enabled ARS and MES to continue research on the effects of sludge entrenchment on soil chemical, physical, and biological properties.

Grants from the Food and Drug Administration, Department of Health, Education, and Welfare, the USEPA Office of Solid Waste Management Programs, Washington, D.C., and the Washington Suburban Sanitary Commission (WSSC) provided further support for research on the toxicity of sludge-borne heavy metals to plants, and their uptake and accumulation by plants when sludges and sludge composts were applied to soils.

SECTION 1

INTRODUCTION

Many municipalities are looking for solutions to their problems of disposal of sewage sludge. As energy costs continue to increase and as wastewater treatment plants across the nation produce larger amounts of sludge, composting will be considered as an alternative to land-fill, ocean dumping, and incineration. Moreover, as abatement and pretreatment measures are implemented, many municipalities now producing sludges with an undesirable content of heavy metals and industrial chemicals will produce sludges that are environmentally safe and acceptable for land application.

Composting of sewage sludge is now being conducted successfully by an increasing number of municipalities throughout the country, while others are seriously considering the practice. This has resulted in an urgent need for a state-of-the-art document on the various aspects of sludge composting and compost utilization.

This manual attempts to fulfill the above-mentioned need. It was written with three principal objectives in mind: 1) to provide municipal planners and decision-makers with information which would assist them in deciding whether composting would be adaptable and economically practical in their local situation, 2) once having made a decision to compost, to provide design information on a rapid aerobic, thermophilic composting method of demonstrated reliability, moderate cost and high environmental acceptability, and 3) to present information on the beneficial use of the compost product as a soil conditioner and source of nutrients for plant growth.

SECTION 2

DEFINITION OF THE PROBLEM AND KEY FACTS ON COMPOSTING AS A SOLUTION

THE PROBLEM

Efforts to reduce the pollution of rivers, lakes, and oceans by treating sewage are generating a rapidly growing amount of sludge, solid material that is removed from a wastewater to produce a clean effluent. Present national production of 5 million dry tons of sludge annually is expected to double by 1985. The increase will be largely due to implementation of Federal legislation that prohibits disposal of sewage into fresh waters (Water Pollution Control Act Amendments of 1972) and oceans (Marine Protection Research, and Sanctuaries Act of 1972). Implementation of these laws will require progressively better treatment through 1985.

Table 1 shows the USEPA estimates of the percentages of 1975 sludge production disposed of by various methods. The U.S. Environmental Protection Agency has ordered that municipalities shall cease all dumping of sewage into the oceans by 1981. As ocean dumping is phased out, use of other methods must increase. Air pollution, which may result during incineration, is subject to stringent regulations imposed by the Air Quality Act of 1967. These restrictions, together with rapidly increasing costs and decreasing supply of petroleum products, reduce the cost-effectiveness of incineration and other thermal methods of sludge processing, and will probably reduce the number of communities that will convert from ocean dumping to this disposal action. To make matters even more difficult, land costs for landfill sites are increasing rapidly and new sites are difficult to obtain.

Since the choice of acceptable management alternatives is decreasing at the same time that sludge production is increasing, the use of land application systems will probably increase substantially. The conversion of sludge to composts is expected to accelerate this trend, especially in large metropolitan areas surrounded by extensive suburbs.

BENEFITS OF COMPOSTING

Sludge composting is the microbial conversion of this material in the presence of suitable amounts of air and moisture

TABLE 1. PERCENTAGE ESTIMATES OF USE OF DIFFERENT MANAGEMENT METHODS FOR MUNICIPAL WASTEWATER SLUDGES IN THE U.S. IN 1975.

Disposal method	Use in % of total
Landfill	35
Landspreading	20
Ocean dumping	20
Incineration	25
Pyrolysis	0
Composting	<1
Thermal dehydration	<1

into a product with the general appearance and many of the other characteristics of a fertile soil. The sludge is conditioned for composting by the use of a bulking material (e.g., woodchips, leaves, refuse) to make it permeable to air. As the aerobic microorganisms biologically oxidize the sludge, they release heat and the sludge temperature increases. In the Beltsville Aerated Pile Composting Method, the mixture is placed over a system of perforated pipes connected to a blower that draws air down through the mass. Exhaust gases are scrubbed through a pile of finished compost to remove odor before their release to the atmosphere. A blanket of compost over the composting sludge prevents odor escape from the surface and insulates the pile so that all of the sludge is exposed to elevated temperatures.

Composting sewage sludge offers several advantages:

1. Microbial decomposition oxidizes the organic material to a fairly stable state resistant to odor production.

2. Heat produced during decomposition destroys many of the human pathogens.

3. The compost is a valuable product when used as a soil conditioner and a source of macro and micronutrients favorable to plant growth.

4. Unlike sludge, the compost can be stored conveniently.

5. Composting uses very little external energy.

Advantages of the Beltsville Aerated Pile Composting Method over the windrow method previously developed are the following:

(1) Satisfactory processing of raw sewage sludge, thereby eliminating the need for expensive digesters or other means of sludge stabilization.

(2) Greater flexibility in scale of operation.

(3) Lower capital costs.

(4) Greater reduction of pathogenic organisms.

(5) Greater flexibility in the ratio of labor to capital.

Aerated pile composting can be used as a permanent sludge management method, or it can be used as a temporary method while a permanent solution to sludge management is being developed. A composting operation may be started on very short notice if a site is available. In many areas, sites could be found that would need little or no preparation. No permanent facilities are required for the process. The only essential major equipment--a front-end loader--can readily be rented. Other equipment, such as the blowers, are stock items. If electricity is not available, portable generators can be rented until service is provided. On a moderate scale and a temporary basis, operations could be commenced on an acceptable undeveloped site within hours. Usually, however, some grading, runoff control, and paving would significantly increase the dependability of the operation.

The relative effects of different wastewater treatment processes on the destruction of pathogens and stabilization of sludge were compared by Farrell and Stern (Table 2). Processes such as pasteurization, ionizing radiation, and heat treatment can eliminate pathogens; however, they leave sludges that are unstabilized and subject to putrefaction when applied to land. Anaerobic and aerobic digestion stabilize sludge, as does composting. However, composting is the only process that provides both good pathogen control and stabilization. Additionally, the compost can be handled and stored easily.

SLUDGE COMPOSITION

The suitability of sewage sludges for processing into compost depends on the characteristics of the wastewater and on the treatment process. The composition of the sludge depends on the type of wastewater treatment (primary, secondary, digestion, etc.), chemical used for flocculation, and sludge source (industrial or domestic). The composting process is not particularly sensitive to the added chemicals, so both digested and undigested or raw sludges can be composted satisfactorily within the pH range of 5

TABLE 2. RELATIVE EFFECTS OF VARIOUS WASTEWATER TREATMENT PROCESSES ON DESTRUCTION OF PATHOGENS AND STABILIZATION OF SEWAGE SLUDGES (ADAPTED FROM FARRELL AND STERN, 1975)

Processes	Pathogen reduction	Putrefaction potential	Odor abatement
Anaerobic digestion	Fair	Low	Good
Aerobic digestion	Fair	Low	Good
Chlorination, heavy	Good	Medium	Good
Lime treatment	Good	Medium	Good
Pasteurization (70^{o}C)	Excellent	High	Fair
Ionizing radiation	Excellent	High	Poor
Heat treatment (195^{o}C)	Excellent	High	Poor
Composting (60^{o}C)	Good	Low	Good
Long-term lagooning of digested sludge	Good	--	--

to 11. Digested sludge, however, has less energy available for raising the temperature to the thermophilic range. Moisture content appears to be the most important characteristic of the sludge for composting. The drier the sludge, the less material there will be to handle in the composting operation and the less it will cost.

Heavy metals content of sludges will vary with the level of industrial contribution. However, we have not found the metal content to affect the composting process. Bulking materials will to some extent dilute the heavy metals content of the sludge.

Under certain conditions heavy metals (zinc, copper, nickel) can kill plants and cadmium can be taken up by plants in concentrations that may be harmful in the human diet. Even domestic wastewater may yield sludges containing enough metals to warrant limiting continuous application. It is apparent therefore, that heavy metal analyses are needed to assess the marketability of the compost to be produced. If levels are high, a source control program may need to be developed in conjunction with the composting program. Analyses and monitoring can be pursued (Appendix) to estimate safe application rates. Table 3 shows the properties of raw and digested sludge compost. The sludges were obtained from the Washington, D.C. Blue Plains Wastewater Treatment Plant and composted with woodchips. Because these sludges are mostly from domestic sources, the derived compost is relatively low in heavy metals and pesticides and, therefore, suitable for land application.

TABLE 3. COMPOSITION OF RAW AND DIGESTED SLUDGES FROM WASHINGTON, D.C., BLUE PLAINS WASTEWATER TREATMENT PLANT AND THEIR RESPECTIVE COMPOSTS PROCESSED AT THE USDA COMPOSTING FACILITY, BELTSVILLE, MD

Component	Raw sludge	Raw sludge compost	Digested sludge	Digested sludge compost
pH	9.5	6.8	6.5	6.8
Water, %	78	35	76	35
Organic carbon, %	31	23	24	13
Total N, %	3.8	1.6	2.3	0.9
NH_4^+-N, ppm	1540	235	1210	190
P, %	1.5	1.0	2.2	1.0
K, %	0.2	0.2	0.2	0.1
Ca, %	1.4	1.4	2.0	2.0
Zn, ppm	980	770	1760	1000
Cu, ppm	420	300	725	250
Cd, ppm	10	8	19	9
Ni, ppm	85	55	-	-
Pb, ppm	425	290	575	320
PCBs1/, ppm	0.24	0.17	0.24	0.25
BHC2/, ppm	1.22	0.10	0.13	0.05
DDE3/	0.01	<0.01	-	0.008
DDT, ppm	0.06	0.02	-	0.06

1/ Polychlorinated biphenyls as Arochlor 1254.
2/ The gamma isomer of benzene hexachloride is also called lindane.
3/ DDE results from the dehydrochlorination of DDT.

ECONOMIC FEASIBILITY OF COMPOSTING

To evaluate the economic desirability of composting for a municipality, one must first evaluate the costs of converting raw sludge into compost and then the benefits the compost will furnish to the community. Benefits will partially offset costs and the net cost of composting may then be compared with the cost of other forms of sludge management.

The cost of composting will vary among projects. Much of the variation will result from differences in physical inputs (i.e., equipment and site preparation) in response to (1) the amount of sludge composted, (2) the topography of the composting site, (3) state and local restrictions, (4) local institutional constraints, and (5) amounts of already existing public works equipment available for the composting. The unit prices of the physical inputs will also differ among localities, adding another cost variable.

Table 4 compares costs of various sludge disposal methods. The wet sludge actually composted contained 23% solids. The dry ton figures presented may be converted to approximate wet tons by dividing by 4.

TABLE 4. APPROXIMATE COMPARATIVE COSTS FOR VARIOUS SLUDGE DISPOSAL PROCESSES, 1976.

Process	Range of costs in dollars per dry ton 3/ 4/
Digested sludges by:	
Ocean outfall	10 to 35
Liquid landspreading	20 to 54
Digested and dewatered sludges by:	
Ocean barging	31 to 44
Landfilling	23 to 53
Landspreading	26 to 96
Dewatered sludges:	
Trenching 1/	116 to 134
Incineration 2/	57 to 93
Heat drying 2/	62 to 115
Composting 2/	35 to 50

1/ Costs exclude transportation of sludge to disposal site.

Table 4 (continued)

2/ Costs exclude cost of removal of residues from the site and benefits from resource recovery.
3/ Cost comparisons require careful interpretation. For example, the cost of digestion should be included in the cost of land-spreading. However, digestion reduces mass of sludge solids by about one-half so there is less sludge to process.
4/ 1 dry ton = 0.908 metric ton (or tonne).

Composting compares favorably in cost with other sludge disposal processes. Landfilling and ocean-dumping may be cheaper in some instances, but they offer no benefits and have serious disadvantages. Incineration is likely to be more expensive than composting and offers benefits only if heat is recovered. Composted and heat-dried sludge will improve the soil. Heat-drying, however involves a large use of energy. Both heat-drying and composting produce a product that is more easily handled and less offensive than digested sludge for use on land. The optimal sludge management system will differ between municipalities due to the variability of the relative environmental, social, and economic ramifications of the alternatives.

Composting dewatered sludge is estimated to cost between $35 and $50 per ton of dry sludge. The higher cost is based on an operation that processes 10 dry tons per day, the lower one on 50 dry tons per day. Economies of size in equipment and labor use decrease the unit cost as the size of the operation increases. These calculations include all on-site expenditures but exclude costs of (1) dewatering the sludge to 20% solids, (2) transporting the sludge to the composting site, (3) treating the runoff from the site, and (4) transporting the compost to the location of its use.

Operating costs account for about 80% of the composting cost per dry ton, with labor accounting for about half of these operating costs and the bulking agent for about a quarter.

The capital costs of composting are not large in relation to such costs in other sludge management options. Capital costs of composting are estimated to be $30,000 to $40,000 per dry ton of daily capacity, although this figure may vary considerably between sites. If these capital costs were increased 10 percent, it would increase the unit cost of composting by less than $1.00 per dry ton.

A cost function for aerated pile composting as practiced at Beltsville, Maryland is presented in Figure 2. It is apparent that operating costs are subject to economies of size which are attained by facilities that compost over 70 dry tons per day.

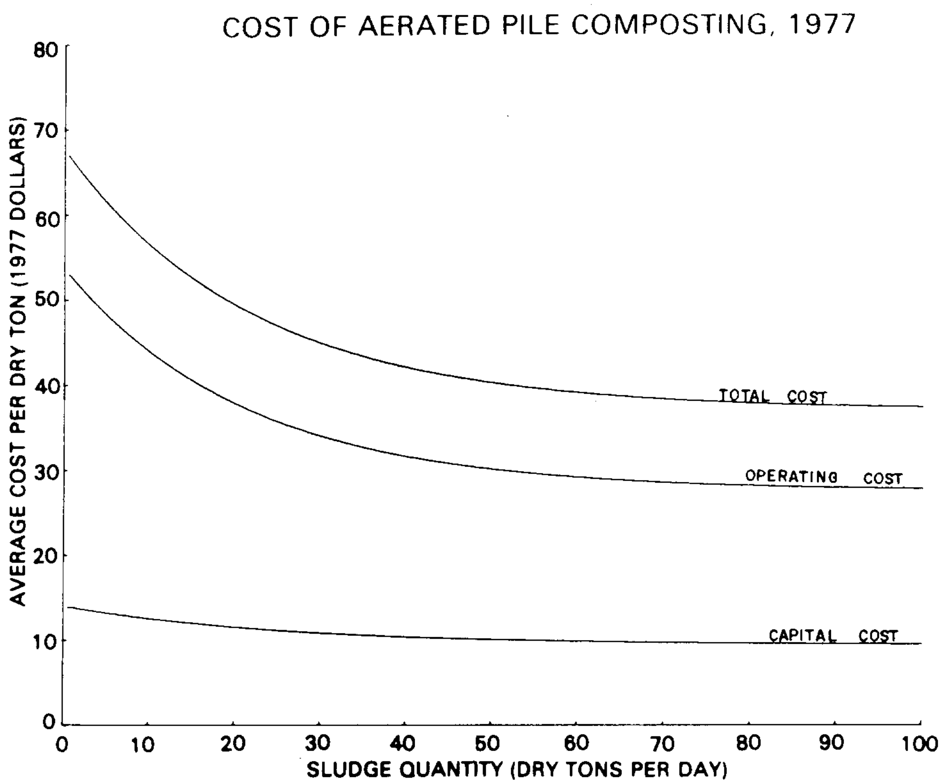


Figure 2. Cost of composting with the Beltsville Aerated Pile Method, 1977.

There will be beneficial uses for all sludge compost that might be produced by including the use of compost for fertilizer on farm land. Compost contains small amounts of nutrients, so the Beltsville compost has a value of about $4 per cubic yard in terms of 1977 prices in Maryland for nitrogen and phosphate. A market study is necessary to determine the net benefits or cost to a community from the distribution of the sludge compost. Some refuse composting operations have closed because of the lack of a developed market for compost in their area and because they expected to show a profit on the production and distribution of the compost. Composting will benefit the sewage authority economically if the net cost of production and distribution is less than that of any other environmentally acceptable disposal system. A well-planned and -managed marketing program is essential to derive a profit over distribution costs, as is the case in Los Angeles County. If the sludge compost is used for its fertilizer value alone, there could be a net cost of distribution, depending on the hauling distance.

Compost may be used in place of peatmoss or topsoil in certain horticultural applications. During preparation for the National Bicentennial, the National Park Service used Beltsville sludge compost to construct Constitution Gardens in the Mall area of Washington, D.C. The Park Service saved over $200,000 by making an artifical topsoil with the compost instead of buying topsoil, which was selling at about $5 per cubic yard undelivered in 1976. The yield of compost is about 5 cubic yards per ton of dry sludge solids, so the net profit or loss on distribution per yard must be multiplied by 5 to obtain the effect per ton of sludge solids.

Composting may be a cost-effective alternative for some municipal sludge management problems. The net cost of composting will vary among municipalities because the production costs and the utilization benefits will also vary. Therefore, a feasibility study of sludge composting must include not only a cost analysis of the process but also a comprehensive analysis of the potential market for the product.

SECTION 3

THE COMPOSTING PROCESS

Composting is an ancient practice used by farmers to convert organic wastes into soil amendments that supply available nutrients to crops and replenish depleted soil organic matter. The practice remained more of an art than a science until about 40 years ago when Sir Albert Howard, a British agronomist in India, developed the Indore Process for composting. Named after the state in India where Howard developed it, the method utilizes a 5- to 6-foot layered pile of various organic wastes such as leaves, night soil, animal manure, sewage sludge, straw, and garbage. The pile is turned after 2, 4, and 8 weeks, and composting is complete in about 3 to 4 months. The method is essentially a combination of aerobic and anaerobic composting. Howard demonstrated that composting is a beneficial alternative to the burning and dumping of refuse and sewage sludge.

The Beltsville Aerated Pile Composting Method stimulates a natural biological process. Complex organic molecules are decomposed into simpler compounds through the growth and activity of bacteria, actinomycetes, and fungi. While these organisms utilize a portion of the carbon and nitrogen fraction in the composting biomass for synthesis of cellular materials, they also convert chemical energy into heat through respiration. This heat raises the temperature of the biomass, evaporates moisture, and raises the temperature of air passing through the biomass. Heat is also lost at the pile surface by radiation, conduction, and convection. A flow diagram for the process, explained at a later point in detail, is presented in Figure 3.

FACTORS AFFECTING THE COMPOSTING PROCESS

A number of factors influence the rate at which composting can proceed and the quality of the finished product.

<u>Temperature</u> Temperature profoundly affects the growth and activity of microorganisms and, consequently, determines the rate at which organic materials are composted. Most of the microorganisms in sewage sludge are mesophilic; that is, they grow best in the temperature range of 20 to 35^{o}C. However, as temperatures increase during composting, a specialized group of microorganisms becomes predominant. These are thermophilic aerobic organisms that develop only at higher temperatures and grow

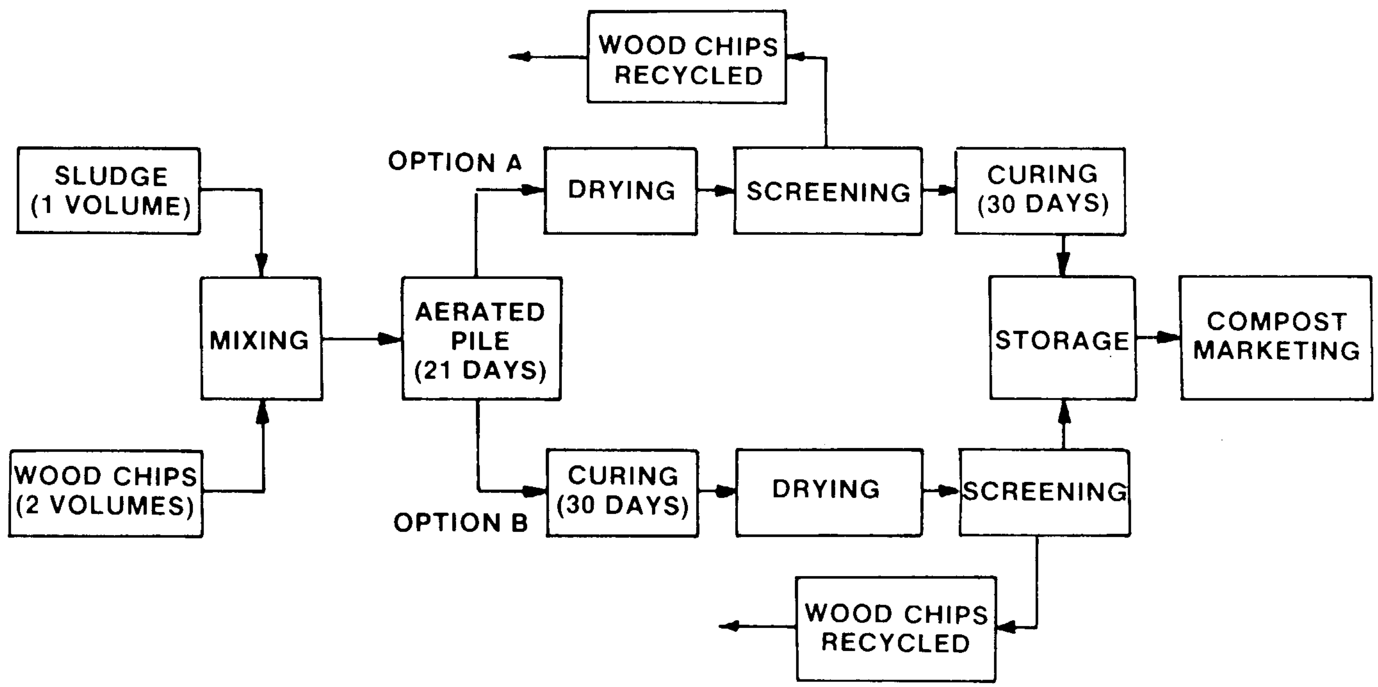


Figure 3. Flow diagram for composting operation.

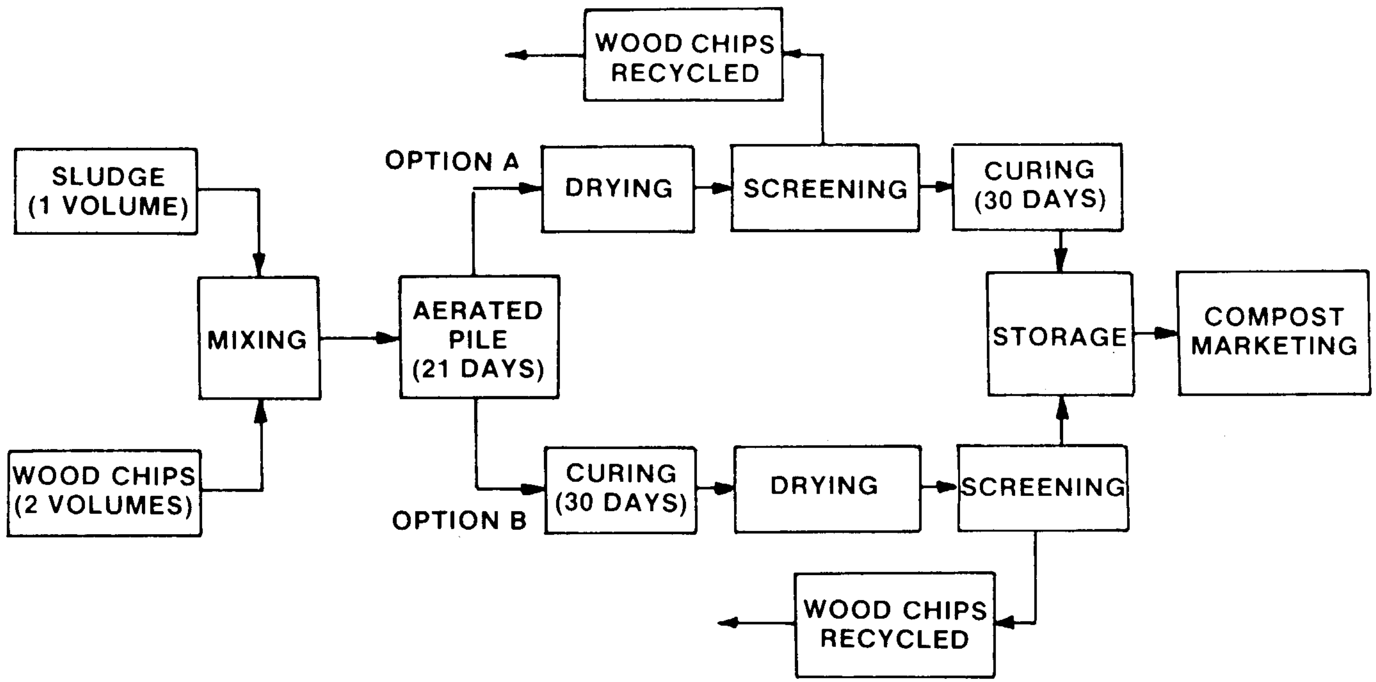
fastest at 45 to 65°C. They generate sufficiently high temperatures to destroy human pathogens.

Carbon:Nitrogen Ratio The C/N ratio is an important parameter in composting because it provides a useful indication of the probable rate of organic matter decomposition. Microorganisms use about 30 parts of carbon for each part of nitrogen. Thus, an initial C/N ratio of 20 to 35 would be most favorable for rapid conversion of organic wastes into compost. Sewage sludges usually have C/N ratios of less than 15. Although decomposition will be rapid at this ratio, nitrogen may be lost as ammonia. In the process described here, the addition of woodchips or other organic bulking materials raises the C/N ratio, ensuring the conversion of available nitrogen into organic constituents of the biomass. The subsequent removal of the woodchips for reuse then lowers the C/N ratio, allowing N to mineralize.

Moisture Content Sewage sludges can be composted aerobically over a wide range of moisture contents, 30% and higher, if aeration is adequate. However, excessively high moisture contents should be avoided in most aerobic composting systems, because water displaces air from the pore spaces and can quickly lead to anaerobic conditions. On the other hand, if the moisture content is too low (less than 40%) stabilization will be slowed because water is essential for microbial growth. The most favorable moisture content for composting sludge (22% solids) with woodchips by the aerated pile method is from 55 to 65% in the sludge-chip mixture.

Aeration and Oxygen Supply In composting sewage sludge, aeration is essential for the development of thermophilic microorganisms to ensure rapid decomposition, odor abatement, and stabilization of the residual organic fraction which remains as compost. Aeration also provides for lowering the moisture content of composting materials that may have initially been too high. The forced aeration system used with the Aerated Pile Composting Method provides for internal oxygen levels of from 5 to 15%. Within this range, maximum temperatures are attained to ensure pathogen destruction and rapid stabilization. Proper control of the aeration rate is essential because too high a rate can lead to excessive heat loss, cooling of the pile, and incomplete stabilization.

Use of Inocula Wherever composting has been practiced, there has been considerable debate as to whether special strains of microorganisms, or other biological factors such as chemical activators, enzymes, and hormones, are necessary to ensure successful composting. A number of these products are commercially available, the contents of which are known only to the manufacturers. However, most organic wastes and residues are already colonized with large numbers of indigenous microorganisms (bacteria, actinomycetes, and fungi) with a wide range of physiological



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pH of the Sludge Sewage sludges can be composted over a pH range of from pH 5 to 10. The most favorable pH range for rapid aerobic composting of sludge would be from 6 to 8, because most microorganisms exhibit maximum growth and activity in that range. Nevertheless, initial pH values as extreme as 5 or 11 do not seem to retard microbiological activity for more than 1 or 2 days. Generally, as composting proceeds the pH shifts toward neutrality.

SITE SELECTION AND DESIGN CRITERIA

Locating the composting site near the wastewater treatment plant results in lower costs for hauling and transportation of sludge, bulking materials, and equipment; a possible reduction of manpower requirements; and more effective utilization of the space allocated for the composting operation. Adverse public reaction to sludge haulage through residential areas may also be avoided.

A sludge-composting facility should comprise the following areas: (a) receiving and mixing, (b) composting pad, (c) drying and screening, (d) curing, (e) compost storage, (f) storage of woodchips or other bulking materials, (g) administrative and maintenance buildings, and (h) driveways. These facilities can be provided for a 10-dry-ton-per-day production rate on a 3.5-acre site.

The sludge and bulking material can be mixed directly on the composting pad with a front-end loader. This mixing procedure is quite satisfactory for small municipalities and requires only a small area for handling materials and maneuvering the equipment. Larger amounts of sludge, i.e., more than 15 dry tons per day, would best be mixed in a stationary mixer (drum mixer or pugmill) located near the filtering equipment. This will substantially decrease the area required for mixing, and also minimize potential problems.

The composting pad should be large enough to accommodate 4 weeks of sludge production by the treatment plant. This will provide for the usual 21-day composting period and the necessary space for operating the equipment. It also will provide a safety margin to allow for extending the composting period beyond 3 weeks if necessary due to low temperatures, excessive precipitation, or equipment malfunction. The odor filter pile will occupy a space equivalent to about 10% of the pile area.

$$\text{Pad area} = \frac{(1.1)(\text{vol. of 4 wks. sludge production})(R+1)}{\text{Av. ht. of sludge layer}}$$

$$\text{where } R = \frac{\text{volume of bulking agent}}{\text{volume of sludge}}$$

The size of the processing area for drying and screening depends on climatic factors, the bulking material used, and the potential use of the product. A considerably smaller area will suffice in hot, dry climates, where the material is relatively dry after composting, than in cool, humid climates. If fine, granular bulking materials are used, the compost may not require screening. For a climate similar to Washington, D.C.,

Processing area = pad area

The curing area should accommodate 30 days of compost production. In regions where compost application is restricted to spring, summer, and fall, the compost must be stored during winter. Thus, the area required for compost storage would be considerably larger in the Northern than in the Southern United States. For Washington, D.C., where compost was stored during the winter,

Curing and storage area = 2 x pad area

In addition to the areas specified earlier, access roads, turnaround space, and a truck-wash area are needed. If the composting site is not near the treatment plant, or if runoff from the site cannot be drained into a sewer system, a runoff collection pond must be provided. Figure 4 shows most of the ARS-MES sludge-composting facility at Beltsville, Maryland, which can compost 20 dry tons of sludge per day.

A buffer zone around the compost site is desirable. Although the Beltsville Aerated Pile Composting Method effectively contains most of the sludge odor, a faint earthy or musty odor of compost remains. Under most weather conditions, this odor dissipates in a very short distance. A screen of trees and shrubbery around the site may reduce the likelihood of odor complaints.

BULKING MATERIALS TO CONDITION THE SLUDGE FOR COMPOSTING

To ensure rapid aerobic composting, the sludge must be mixed with a suitable bulking material to provide the necessary structure, texture, and porosity for mechanical aeration. The bulking material, which is usually organic, can also function as a carbon carrier to provide extra energy for the microorganisms during composting. While some decomposable carbon in the bulking material is desirable, it is not essential to the composting process.

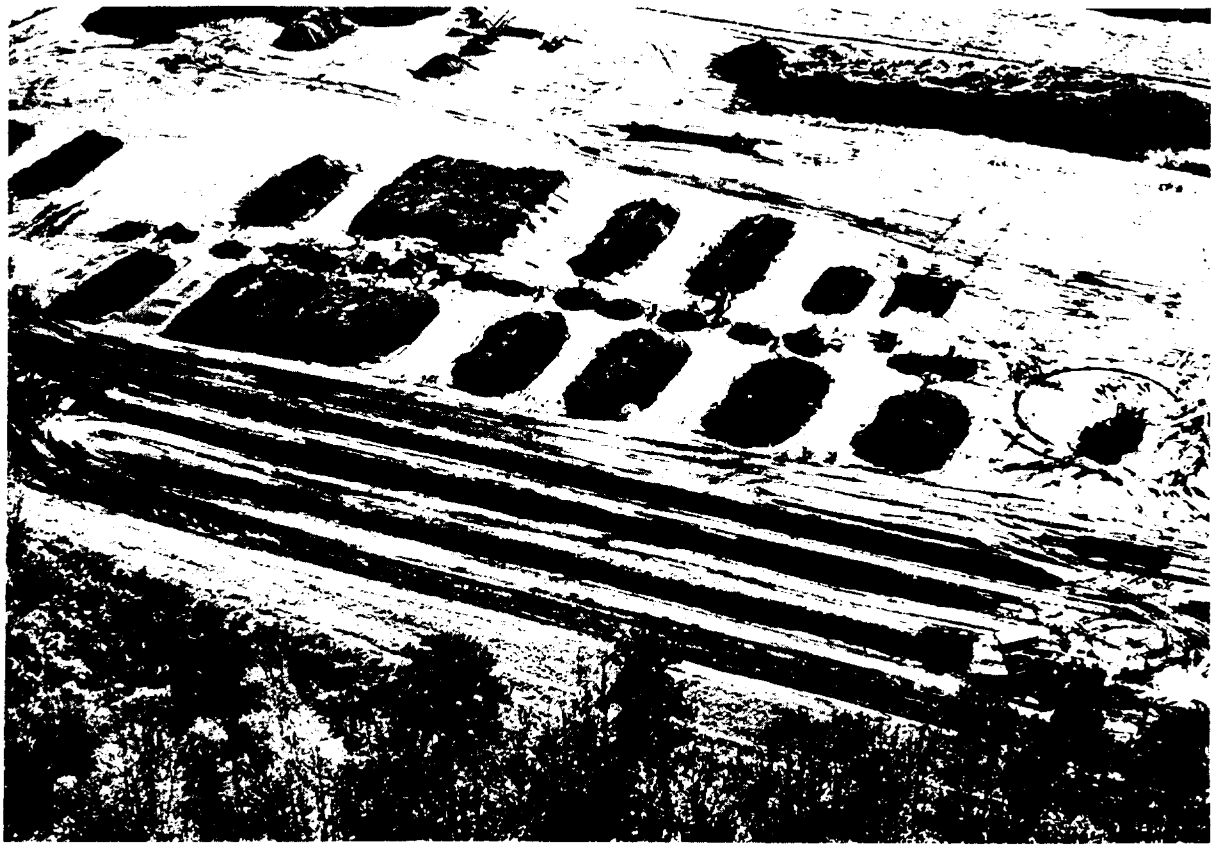


Figure 4. Aerial view of sludge-composting research site. Windrows in foreground are being used to dry compost prior to screening. Extended pile adjacent to windrows contains as much sludge as five of the individual aerated piles. Piles in upper portion of picture are stored compost. Weather has caused no interruptions in the processing rate of 60 T/day, 5 days per week during the 4 years that aerated pile composting has been the major mode of operation.

The amount of bulking material needed is related to moisture content of the sludge. For example, liquid sludge at 6 to 8% solids would require about 5 to 7 times as much of a given bulking material as partially dewatered sludge at 22 to 24% solids. Bulking materials should have sufficient wet strength to allow the necessary porosity for air movement when mixed with the sludge and placed in the pile. These materials also should have sufficient moisture absorptive capacity to induce crumbling of the sludge. Because most of the decomposition during composting occurs at exposed surfaces, crumbling speeds stabilization by increasing the surface-to-volume ratio. The upper limit for good crumbling of sludge is at a moisture content of about 60%.

Many materials frequently considered wastes have the properties of a suitable bulking agent in some degree, e.g. woodchips, wood shavings, sawdust, peanut hulls, corncobs, leaves, refuse (garbage), cotton gin trash, sugarcane bagasse, pelleted refuse-derived fuel (RDF), rice hulls, cereal straws, shredded bark, and various air-classified fractions (mainly paper) from solid waste recovery plants.

Landfill operators may have valuable information on sources and amounts of waste materials that might be used as bulking materials for the composting of sewage sludge. The amount of bulking material needed will vary with the material selected and the sludge. For a partially dewatered sludge of 20% solids, the most effective bulking material-to-sludge ratio has ranged between 1:1 and 4:1 on a loose volume basis. The mixture should be porous and contain no free liquid. Some bulking materials can be recovered by screening and used several times; others might need to be screened out and landfilled; some might become a part of the compost. The influence of the bulking material on the value of the compost should not be overlooked.

Woodchips have been the most commonly used bulking material for composting sewage sludges at USDA's Composting Research Facility at Beltsville, Md., because of their low cost and guaranteed availability.

THE MIXING OPERATION

The sludge and bulking material must be thoroughly mixed so that lumps of sludge are no larger than 3 inches (7.5 cm) in diameter. If sludge aggregates are larger than this, a slow rate of decomposition and suboptimal temperatures may result.

A number of different machines (Figures 5-8) can be used to achieve this desired degree of mixing, for example, a front-end loader. Another method is to spread the bulking material and sludge in layers, and then to mix with a rototiller. Windrow turning machines can also be used effectively, but their cost

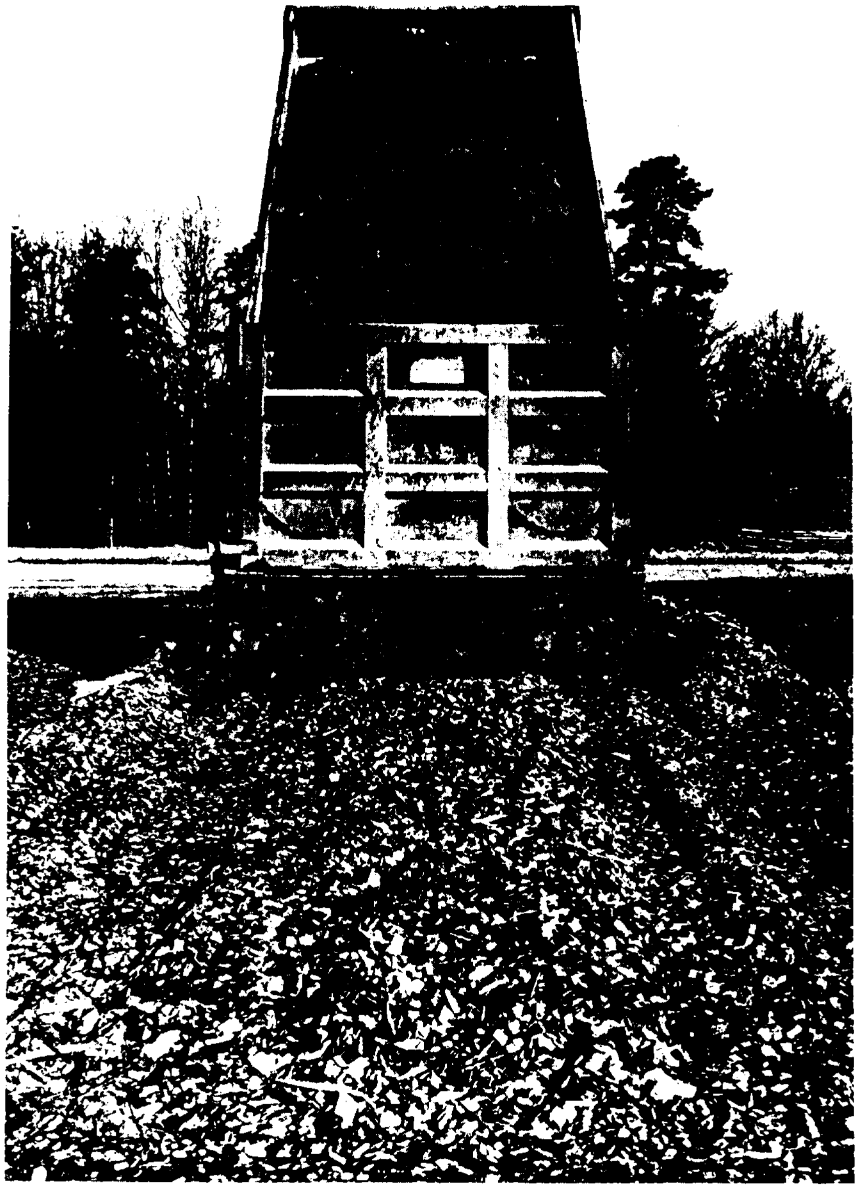


Figure 5. Dump truck load of vacuum filter cake sludge from the Blue Plains Waste Water Treatment Plant being unloaded onto a bed of woodchips with which it will be mixed.

Figure 6. Front-end loader distributing sludge uniformly over bed of woodchips prior to mixing. The loader may also be used for the entire mixing operation.

Figure 7. Terex-Cobey windrow composter mixing sludge with woodchips. This method of mixing might be suitable for treatment plants producing 100 dry tons of sludge daily.

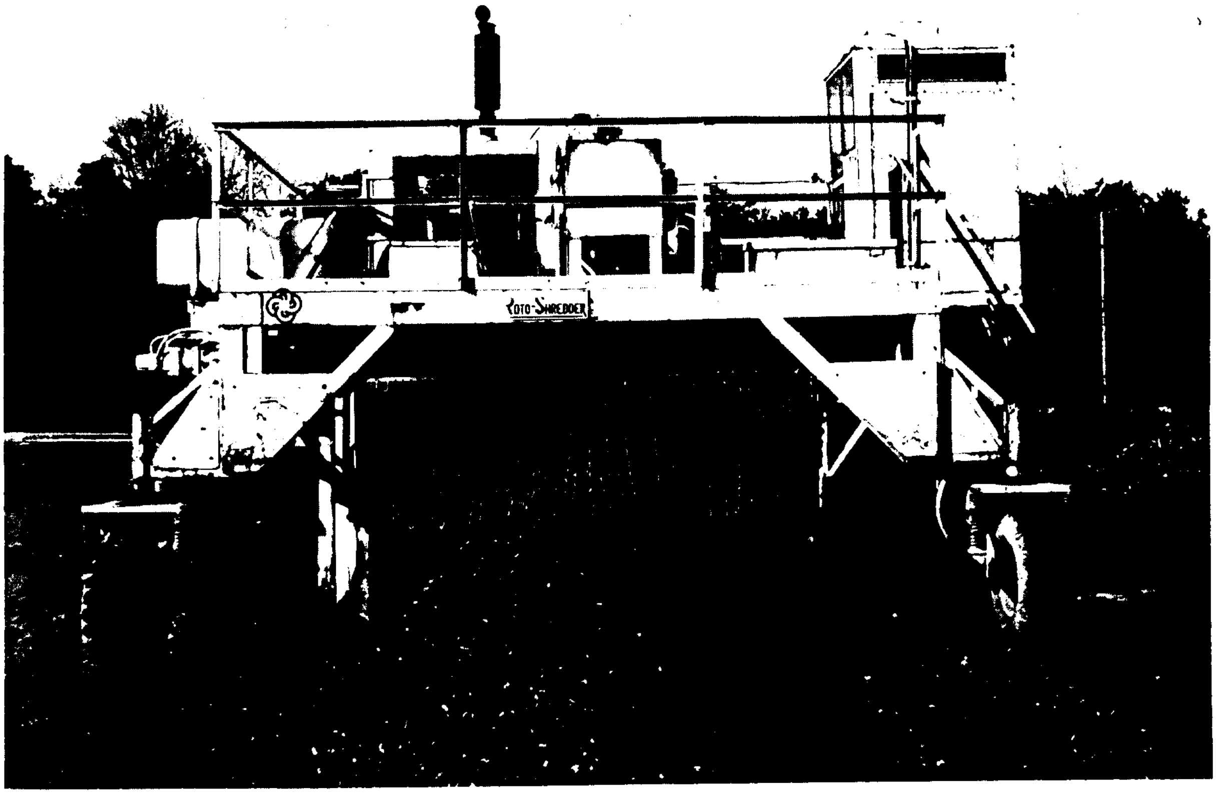


Figure 8. Roto-shredder, another windrow composting machine, mixing sludge with woodchips.

makes their use more applicable to operations that handle several hundred tons of sludge (22% solids) per day.

Drum mixers and pugmills may also be used in the mixing operation. However, the stickiness of the sludge and the flow characteristics of the bulking material are important considerations in designing systems that can successfully feed and unload them. With such mechanization it may be necessary to increase the bulking material:sludge ratio to compensate for variations in proportioning.

THE AERATED PILE

A three-dimensional schematic diagram of the Beltsville Aerated Pile Method for composting sewage sludge is shown in Figure 9. In their simplest form, the individual aerated piles are constructed as follows:

1. A loop of 4-inch-diameter (10-cm) perforated plastic pipe is placed on the composting pad lengthwise and directly under what will become the ridge of the pile (Figure 10). The perforated pipe should not extend under the end slopes of the pile because too much air may be pulled through the sides, causing localized "cold spots" that do not reach the thermophilic range.

2. A 6- to 8-inch (15- to 20-cm) layer of woodchips or other bulking material is placed over the pipe and the area to be occupied by the pile. This layer comprises the pile base and facilitates the movement and distribution of air during composting. The base material also absorbs excess moisture that may condense and leach from the pile.

3. The mixture of sludge and woodchips is then placed loosely upon the prepared base with a front-end loader or conveyor system (Figures 11 and 12) to form a pile with a triangular cross section 15 feet wide (5 m) and 7.5 feet high (2.5 m).

4. Excess woodchips are removed from around the base and the pile is completely covered with a 12-inch (30-cm) layer (often referred to as the "blanket") of cured, screened compost or an 18-inch (45-cm) layer of cured, unscreened compost to provide insulation and prevent the escape of malodorous gases during composting. If finished compost is not available, as would be the case for the first piles of a new operation, the bulking material can be used. However, the blanket thickness may have to be increased to achieve the same degree of insulation and odor control as obtained with cured compost.

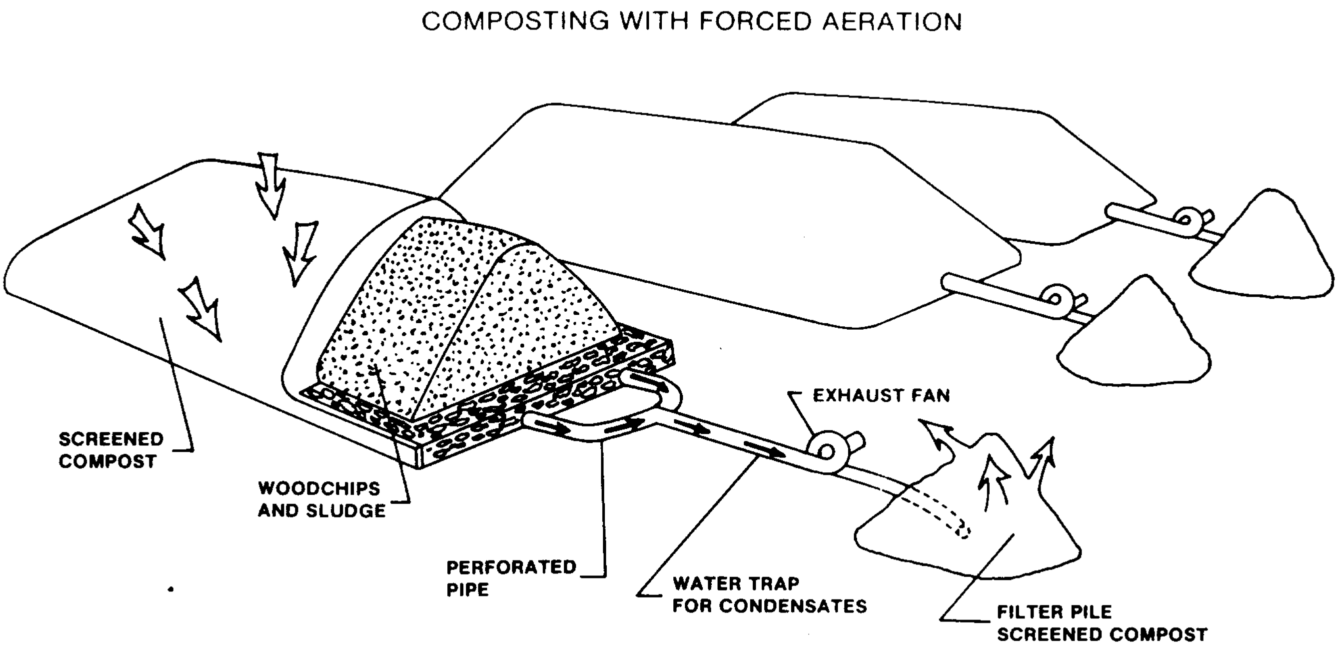


Figure 9. Schematic diagram of an aerated pile, showing location of aeration pipe. The piping under the pile is perforated for air distribution.

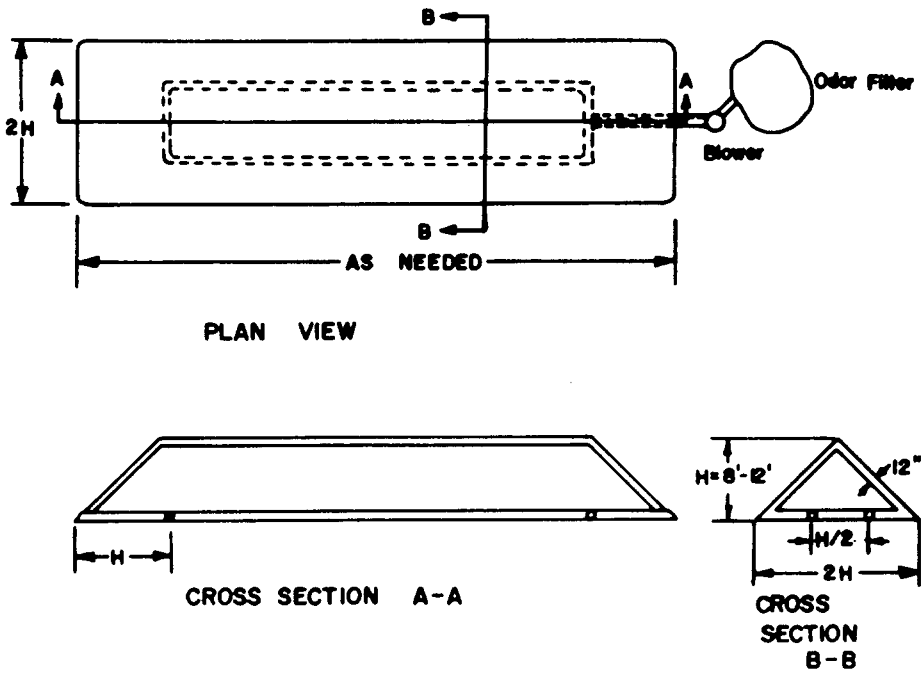
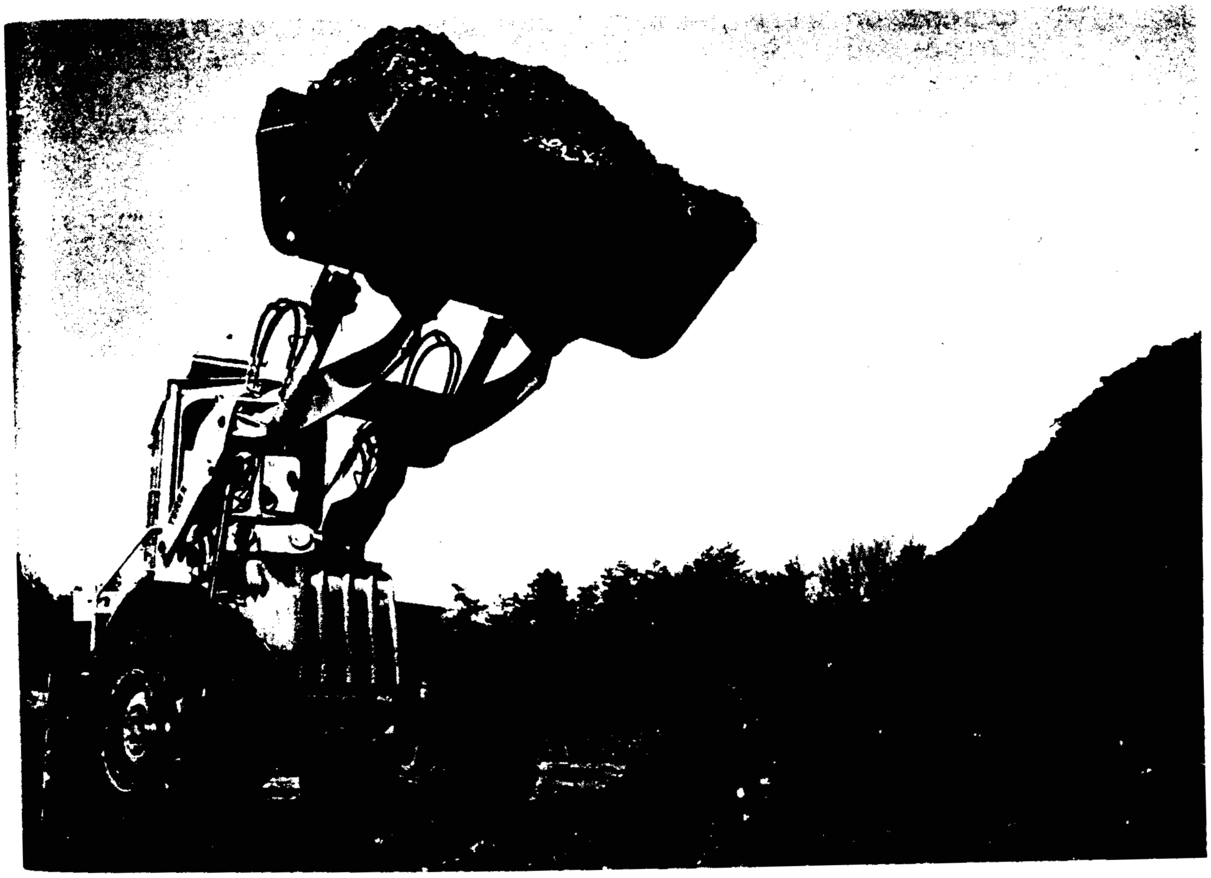


Figure 10. Orientation of aeration pipe in pile, indicating recommended edge distances and spacing for extended piles.

Figure 11. Front-end loader placing sludge-woodchips mixture on aerated pile. Note air conditioner on top of cab which enables operator to work in relatively dust-free environment.



igure 12. Front-end loader about to place sludge-woodchips ixture on aerated pile. Loader wheels ride up on the woodchip ase but not on the mixture since they would compact it, thus locking air movement.

5. During construction of the pile base, the perforated pipe is connected to a section of solid plastic pipe extending beyond the pile base. The solid pipe is connected to a blower rated at 160 cfm with 5" water head powered by a 1/3 - hp motor and controlled by a timer (Figure 13). The actual air resistance of this entire system has been less than 5" so that the actual air delivery has been 200 to 250 cfm. Aerobic composting conditions are maintained by drawing air through the pile intermittently. The exact aeration schedule will depend on pile geometry and the amount of sludge to be composted. For a pile with the dimensions described (20 m x 5 m x 2.5 m), the timing sequence for the blower is 4 minutes on and 16 minutes off. The composting begins when the blower is turned on.

6. The effluent air stream discharged from the compost pile blower is conducted into a small cone-shaped pile of cured, screened compost approximately 4 feet high (1.3 m) and 8 feet in diameter (2.7 m), where malodorous gases are absorbed. These are commonly referred to as odor filter piles. The moisture content of compost in the filter pile should not exceed 50% because the odor retention capacity tends to decrease at higher contents. A 6-inch (15-cm) base layer of woodchips or other bulking material around the perforated pipe will minimize back pressures, which could cause leakage of malodorous gases around the blower shaft. The odor filter pile should contain about 1 cubic yard of screened compost for each 10 wet tons of sludge being composted.

   With new operations, where screened compost is not yet available, some bulking material or soil (or a mixture thereof) could be used in the filter piles.

Variations in pile shape and size can adapt the process to differences in the rate of sludge production by most treatment plants. The individual pile method described here is suitable for operations ranging from as little as 5 tons of sludge (20% solids) from a single weekly dewatering operation in a cone shaped pile to more than 100 tons per week.

THE EXTENDED AERATED PILE

Another version of the aerated pile is the aerated extended pile illustrated in Figure 14. Each day's sludge production is mixed with a bulking material and added against the slope of the previous day's pile, thus forming a continuous or extended pile. The extended pile offers certain advantages for larger municipalities on a daily sludge production schedule. For example, the area of the composting pad can be reduced about 50% as compared

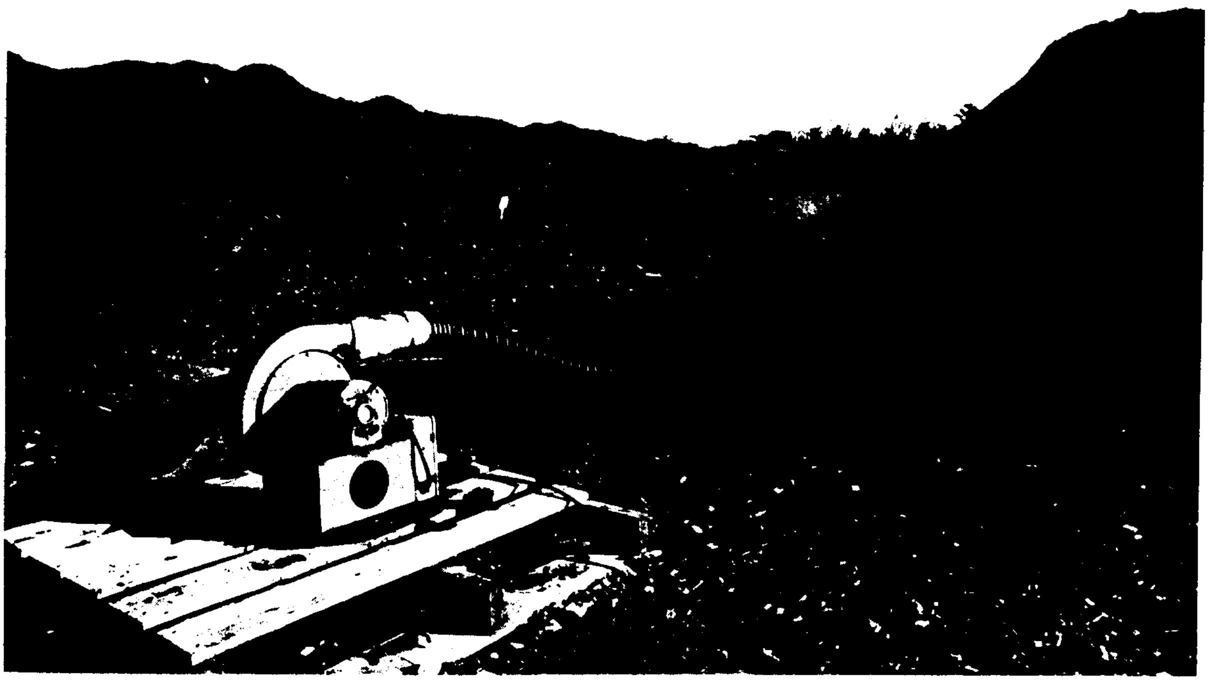


Figure 13. Axial vane centrifugal fan powered by a 1/3 horsepower electric motor. Steam is escaping from the odor filter pile on the right. Fan is controlled to operate intermittently by a time clock. Typically, the time clock is set to operate motor for 4 minutes out of 20 when serving 50 tons of vacuum filter cake.

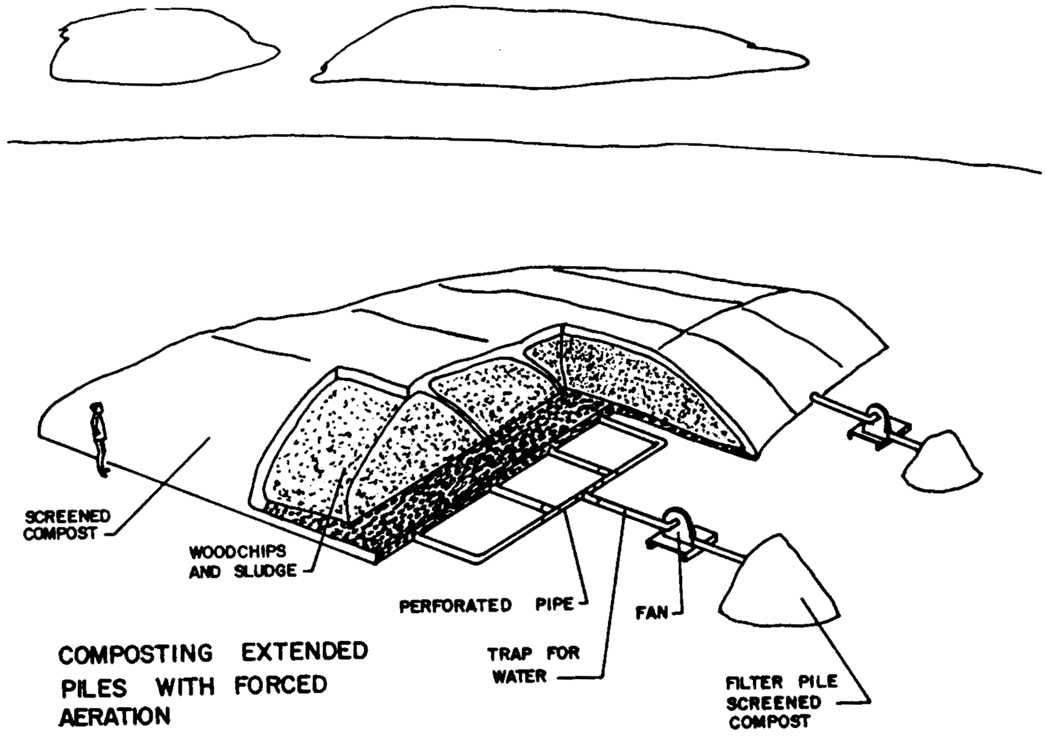


Figure 14. Schematic diagram of extended aerated pile showing construction of pile and the arrangement of aeration pipe.

with that required to accommodate an equal amount of material in individual piles. Moreover, the amount of screened compost blanket material needed for insulation and odor control and the amount of bulking material for the pile base are decreased 50%.

In constructing an extended pile, the first day's sludge production is placed in an individual pile with triangular cross section as described earlier, but only one side and the ends are blanketed. The remaining side is dusted with about an inch (2.5 cm) of screened compost for overnight odor control. On the second day, additional aeration pipe is placed on the pad surface parallel to the dusted side, the pile base is extended, and the sludge-woodchips mixture is placed in such a manner as to form an extended pile with a trapezoidal cross section as shown in Figure 15. Also on the second day, the flat top and ends are blanketed with screened compost and the remaining side receives a thin layer of compost as before. The pile is extended in this fashion each day for 28 days. However, after 21 days the first day's section is removed for either drying and screening or placing in a curing pile. After the removal of seven sections in chronological sequence, sufficient space is freed for operating the equipment so that a new extended pile can be started where the old one had been. Thereafter, a section is removed each day from the old pile and a section is added to the new one.

TEMPERATURES ATTAINED DURING COMPOSTING

The transformation of sludge into compost is essentially complete after 3 weeks in the aerated pile. Microbial decomposition of the volatile organic fraction of the sludge in an aerobic atmosphere soon raises the temperature throughout the pile to above 140°F (60°C), which effectively destroys pathogenic organisms that might cause disease in humans. Typical temperatures recorded during the composting of raw sludge by the Beltsville Aerated Pile Method are shown in Figure 16. Temperatures in the pile increase rapidly into the thermophilic range of 176°F (80°C) or higher. Temperatures begin to decrease after about 16 to 18 days, indicating that the microflora have used the more decomposible organic constituents and that the residual sludge has been stabilized and transformed into compost. Figure 16 also indicates that if piles are constructed properly, neither excessive rainfall nor low ambient temperatures affect the composting process.

AERATION AND OXYGEN SUPPLY

Centrifugal fans with axial blades are usually the most efficient mechanism for developing the necessary pressure to move air through the compost piles and into the odor filter piles. About 5 inches (12.5 cm) of water pressure across the fan has

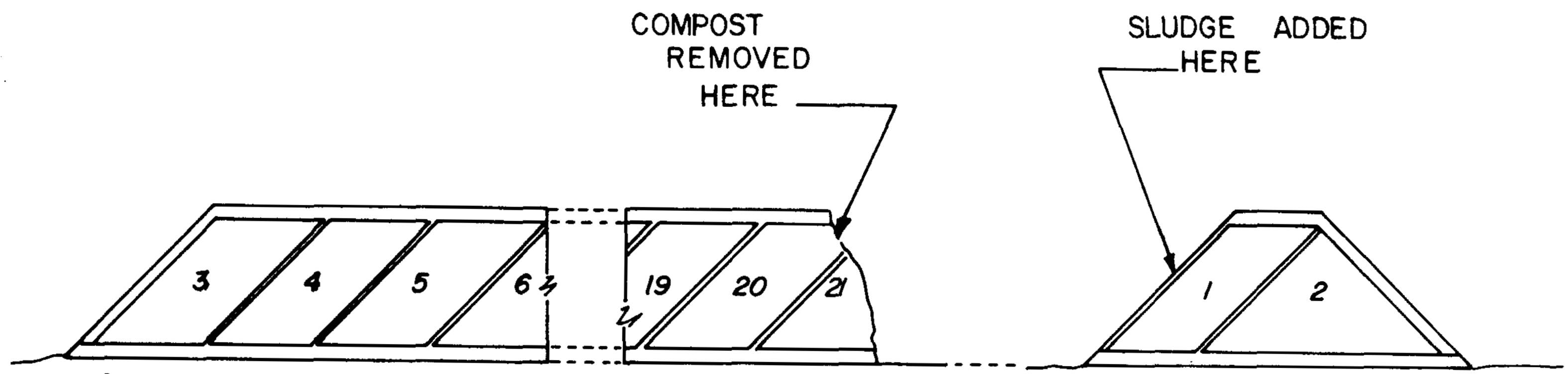


Figure 15. Cross section of an extended pile showing a typical sequence of sludge additions to the pile. Numbers indicate the age of the compost in days.

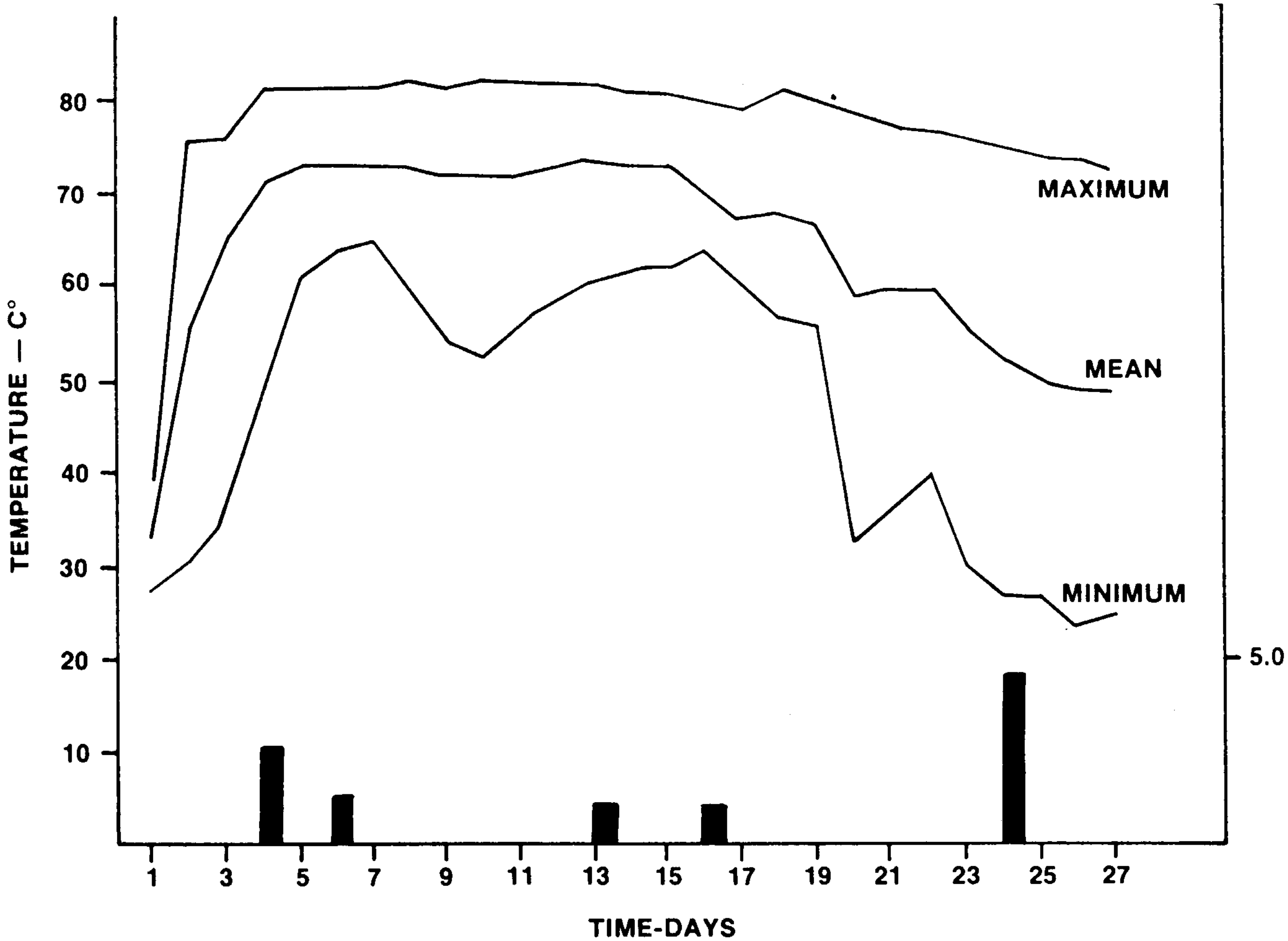


Figure 16 Temperatures recorded during the composting operation. Bars at bottom indicate rainfall events.

been adequate when woodchips are used as the bulking material. However, when finer textured materials such as sawdust are used for composting sludge, a substantial increase in pressure may be needed.

An aeration rate of about 500 cubic feet ($14m^3$) per hour per ton of sludge (dry weight basis) should maintain the oxygen level in the pile between 5 and 15% and provide for rapid decomposition of the sludge and extended thermophilic activity. Continuous aeration results in rather large temperature gradients within the pile. Cycles of 20 to 30 minutes, with the fan operating 1/10 to 1/2 of the cycle, have given more uniform temperature distribution.

The air under the compost piles is collected and delivered to the odor filter piles by 4-inch (10-cm) flexible plastic drain pipe. The pipe is damaged beyond reuse when the piles are taken down, but since it is relatively inexpensive it is considered expendable. Rigid steel pipe has also been used and can be pulled lengthwise out of the pile without damage for reuse. Pipe spacing for the extended piles should not exceed the pile height. The pipe should be large enough so that the air velocity does not exceed 2,000 ft. per minute to prevent excessive pressure variation. Manifolding the outer ends of the pipe will equalize pressure should the pipe be damaged.

CONDENSATE AND LEACHATE CONTROL

As air moves down through the composting sludge, it is warmed and picks up moisture. However, as a result of heat loss to the ground, temperatures near the base of the pile are slightly cooler. As the air reaches this area, it is cooled slightly, causing moisture to condense. When enough condensate collects, it will drain from the pile, leaching some sludge with it. Condensate will also collect in the aeration pipes and, if not drained, can accumulate and block the air flow. Leachates and condensate combined may amount to as much as 5 gallons per day per ton of dry sludge. If the bulking material is sufficiently dry when mixed, however, no leachate will drain from the pile. Since the leachate contains sludge, it can be a source of odor if allowed to accumulate in puddles, so it should be collected and handled in the same manner as runoff water from the site.

SEQUENCE OF OPERATIONS FOR COMPOSTING SLUDGE

A flow diagram for the Beltsville Aerated Pile Method for composting sewage sludge is shown in Figure 3. After 21 days of composting, there are two options which provide considerable flexibility for the process. If weather and climatic conditions are favorable and labor and equipment are available, option A is usually followed, whereby windrow drying and screening are performed before a 30-day curing period is imposed. The compost and woodchip mixture is usually dried to about 40 to 45 percent moisture to facilitate clean separation of compost from chips by screening. The recovered woodchips are recycled with new batches of sludge. If the weather is inclement or labor and equipment are not available, option B can be followed, whereby the composted biomass is taken directly from the aerated pile and placed in a curing pile for 30 days before drying and screening. Not only does this provide processing flexibility but it offers the choice of two kinds of compost - users of compost for land reclamation and erosion control often prefer the unscreened compost containing woodchips.

The curing and any subsequent storage can be considered as an extension of the composting process and are associated with elevated temperatures, though somewhat lower than the mean temperatures attained during the initial composting. Curing ensures total dissipation of phytotoxic gases and offensive odors, and allows for total destruction of any remaining pathogens.

Drying The moisture content of the compost can substantially influence its handling characteristics. When the moisture content is 45% or less, the compost will flow freely and can be handled or screened without difficulty. Good handling characteristics are also advantageous for the users of the product. The moisture content should not be below 35%, since dusting becomes a problem at lower moisture contents.

Two methods of mechanically assisted drying have been used at Beltsville. In the first method, the compost is spread out in a 12-inch layer and harrowed frequently with a spring tooth harrow mounted on a small farm tractor. In the second method, the compost is placed in a windrow 3 feet high and turned frequently. Generally, 1 to 2 days of drying by either method is adequate if the compost is worked hourly. Regularly updated weather forecasts are essential when drying the compost by either of these methods. When precipitation is predicted, the compost should be piled to minimize the surface exposed. Heavy precipitation will increase moisture only slightly in storage piles more than 10 feet (3 m) high. The same methods can be used for drying wet bulking material when necessary.

Screening Depending on the bulking agent used, operators may find it desirable to screen the compost to improve its marketability or to remove the bulking material for reuse (Figures 17 and 18). These choices are largely governed by economics. When a coarse bulking agent is used, some screened compost is desirable for blanket material. Both rotary screens (trommels) and vibrating screens have been used satisfactorily. The rotary screens, however, have been less susceptible to clogging when screening compost at higher moisture contents. A 1/4 to 1/2-inch screen opening will produce a product that is attractive for most

Figure 17. Rotary drum (trommel) screen separating woodchips from composted sludge. Conveyor in foreground is delivering compost. Moisture content of compost must be less than 50% to prevent bridging in feed hopper.

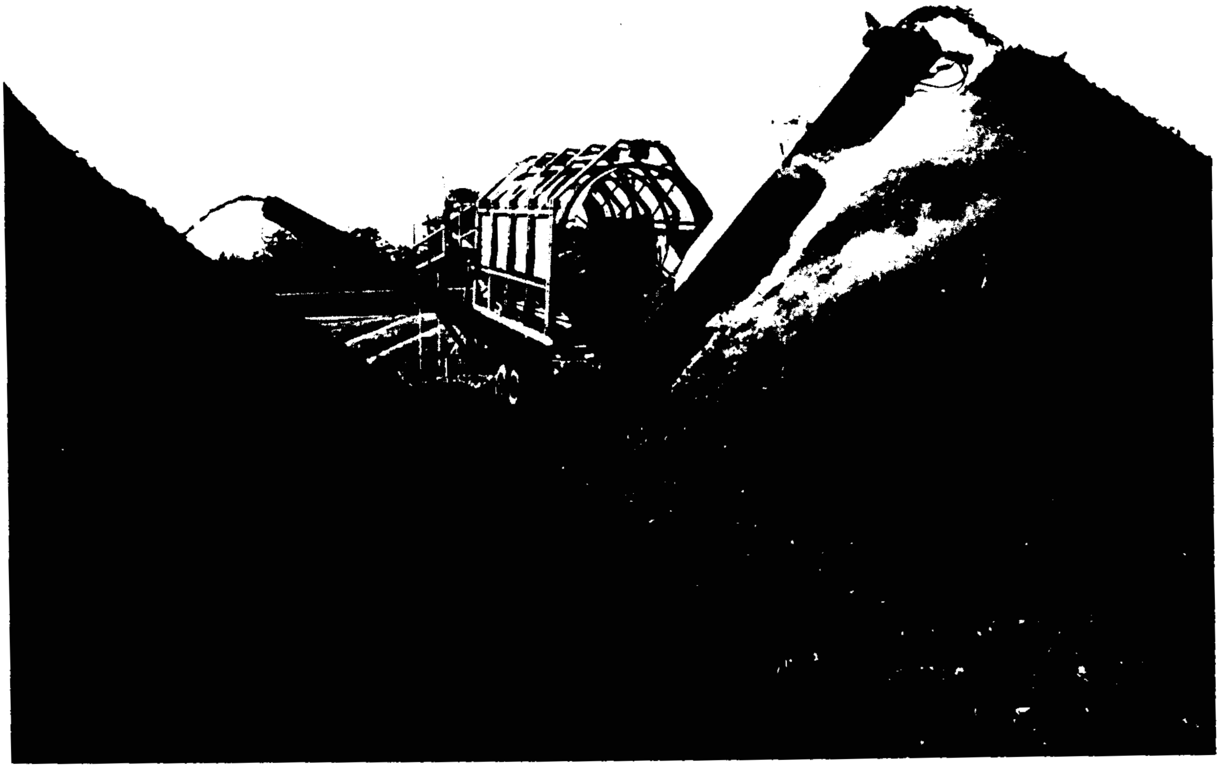


Figure 18. Still-warm woodchips steaming in foreground. Reclaimed woodchips are reused as bulking material until they decompose and become part of the compost after about 4 to 5 uses.

soil conditioning uses.

Curing and Storage After the compost has been cured for about 30 days (screened or unscreened), it may have to be kept in a storage pile. Use of the compost will be somewhat seasonal, i.e., most of it will be applied either in the spring or fall. Thus, a storage capacity to accommodate 3 to 6 months' production will be needed.

During storage, the compost will continue to decompose slowly. Usually, this does not present any problem because by this time the compost is well stabilized. Decomposition in storage can be largely curtailed by drying the compost to a moisture content of about 15%. If it is stored in large piles at a moisture content of, say 45%, temperatures will increase to the thermophilic range, and additional composting will occur. The compost can be stored without cover and may be piled as high as is convenient with the equipment available. The tops of the storage piles should be rounded so that wet pockets do not develop.

MONITORING OPERATIONS

The aerated pile composting process is relatively insensitive to changes in operating conditions and materials. However, to achieve economy of operation, produce a product of adequate quality, and reduce potential for pollution, control and monitoring of operating parameters is necessary. Since microbiological activity during composting is mainly influenced by temperature, oxygen, and moisture content, these parameters should be monitored so that improper composting conditions can be corrected. Composting as described here is a batch process, making it important to collect some data on each pile or each section of an extended pile.

The most common cause of difficulties is excessive moisture in the composting mixture. The maximum moisture content for consistently good composting activity will be about 60% wet basis of the sludge-bulking agent mixture. A skilled operator will soon learn to identify this limit by appearance, as well as by the moisture content of the bulking material needed to produce a compostable mix.

Temperature will reveal more about the process than any other single measurement. Temperatures should be measured at several locations in the pile. Continuous measurement is not needed, but remote recording of temperature from several thermocouple or thermistor probes may be more cost-effective than periodically sending out an operator to take measurements.

Most of the compost pile should reach 130°F (55°C) within 2 to 4 days, indicating satisfactory conditions with respect to moisture content, bulking material ratio, mixing, and pH. If substantial portions of the pile exceed 175°F (80°C), the aeration rate can be increased to remove additional moisture from the pile. Temperature also is an excellent indicator of the probable extent of pathogen destruction or survival. Pathogens die off rapidly when temperatures are 130°F (55°C) or higher for several days. Some temperature measurements should be taken just inside the blanket, where cold spots are most likely to occur. Cold spots may result from a thin place in the blanket, from the placement of an aeration pipe too close to the edge of the pile, from excessive pad material not covered by the blanket, or from incomplete mixing. If the average temperature in the pile is below 140°F (<60°C) after 5 to 7 days, the cause should be determined and corrected. If, as is most likely, the moisture content is too high, additional dry bulking material can be mixed in and the pile rebuilt. Two other possible causes of low temperatures are an excessive aeration rate (also indicated by high oxygen levels) and high sludge pH (>11.0). Equipment recommended for monitoring temperatures is listed in the appendix.

Oxygen analysis of gas samples drawn from the center of the piles is useful for locating problems and optimizing the aeration system. The oxygen level should be in the range of 5% to 15% the first week. Scattered readings below 5% indicate poor distribution or movement of air, probably due to excessive moisture or incomplete mixing. If a gas sample cannot be obtained, there are no voids for oxygen movement and the sampling location is probably anaerobic. If all readings are low, the aeration rate should be increased. High aeration rates to maximize drying will increase the oxygen level to as much as 20% during the third week of composting. Equipment recommended for monitoring oxygen levels during composting is listed in the appendix.

The maximum allowable level of pathogens or heavy metals in the compost may eventually be set by federal or state regulations, in which case the sampling procedures and frequency will be prescribed by the regulatory agency. However, a record of operating temperatures showing that the temperature of the coldest part of the pile had exceeded 60°C would indicate that most pathogens were killed.

Site operators should pay particular attention to odors. Whenever unpleasant odors are noted, the source should be located and corrected. Exposed sludge, ponding around compost piles, and partially composted sludge are potential odor sources. Improperly constructed odor filter piles or leaky pipes between the blower and the filter pile can also contribute odors. Over time, the odor filter piles tend to collect condensate, which lowers their capacity to absorb and retain odors. When the moisture content of the odor filter piles becomes excessive (i.e., 75 to 80%), they should be removed and rebuilt with dry (50% moisture content or less) compost. The used filter pile compost can be placed in a curing pile for reconditioning. A recommended procedure for measuring the moisture content of compost or bulking materials is described in the appendix.

The blowers should be checked daily to see that they are operating. Whenever the bulking agent or the air distribution system is changed, the air delivery rate should be checked.

Table 5 lists parameters that should be monitored during the composting operation, and the suggested frequency of measurement in accordance with the size of operation.

Table 5. Suggested parameters and time sequences for monitoring

Parameter	Size of operation in tons per week (dry solids)		
.	<25	25 to 250	>250
Moisture content[1]	monthly	weekly	daily
Temperature	daily	daily	daily
Oxygen	optional	weekly	daily
Pathogen survival	as required by local regulations		
Heavy metals	as required by local regulations		
Process odors	daily	daily	daily
Blower operations	daily	daily	daily
pH of sludge[2]	monthly	monthly	monthly

1 Qualitative "by eye" estimation of moisture of the compost mix should be done daily. Moisture content of sludge should be obtained from sewage plant operator.

2 Good communications should be maintained with sewage plant operators, so that the compost plant operator is informed of any process change or condition that will effect the quality of the sludge.

ODOR CONTROL

Although sewage sludge can emit a strong unpleasant odor, this odor gradually disappears as the sludge is stabilized by composting. All odor cannot be eliminated during composting, however. Even well-cured sludge composts have an earthy odor that fortunately is pleasant to most people.

Each of the unit operations can be a potential source of odors. Some of the odors are emitted intermittently and others continuously. Odor potential increases considerably during and immediately after heavy precipitation. To minimize the odor potential throughout the composting process, one must manage each operation as follows:

1. The mixing operation -- Prompt mixing of sludge and bulking material and placement of the mixture in the aerated pile reduces the time for odor generation. Lime added to the as a conditioner for dewatering or added with the bulking material will help to lower the odor intensity. An enclosed mechanical mixer could eliminate the release of odors during this operation.

2. Aerated pile surface -- This will not be a source of strong odors if the blanket of compost is adequate for insulation. Thin spots or holes in the blanket will be a potential source of odors. The effectiveness of the blanket for odor control decreases when its moisture content exceeds 60%.

3. Air leakage between the blower and odor filter pile -- Since air leakage can occur at this point, all pipe joints should be sealed. Back pressure from the odor filter pile should be minimized to prevent gaseous losses around the blower shaft. A layer of woodchips over the perforated pipe will minimize back pressures.

4. Odor filter piles -- Odor filter piles should be cone-shaped and symmetrical, and should contain about 1 cubic yard of dry (50% moisture or less) screened compost per 10 wet tons of sludge being composted. A small cone of woodchips over the pipe outlet will reduce pressure through the pile.

5. Condensate and leachate -- As these liquids drain from the compost pile, they should be collected into a sump and conveyed in a pipe to the sewer system or runoff pond.

6. Removal of compost from the aerated pile to the curing pile -- Excessive odor during this operation can probably be attributed to inadequate stabilization of the compost due to too high a moisture content of the bulking material. The situation is prevented by using drier materials in the initial mixing operation. See item 7 (below) for overcoming the problem if it occurs.

7. Curing piles -- These also can be a source of odors if the material removed from the aerated pile has not been completely stabilized. Blanketing the curing pile with dry cured compost will help to contain any odors. If sludge is incompletely composted after 21 days because of excess moisture, low temperatures, improperly constructed piles, or improperly treated sludge, it should not be put on a regular curing pile. Instead it should be mixed with additional bulking material and composted another 21 days with aeration, or put into a separate isolated pile, heavily blanketed with screened compost, and allowed to compost anaerobically for 6 to 8 months.

8. Storage piles -- Piles should not be constructed with excessively wet compost (above about 55% moisture. The compost should be dried by the procedures outlined above (see "Sequence of Operations - Drying") before piling for storage.

9. Aggregates or clumps of sludge -- When aggregates of sludge, even though small, are allowed to remain on the compost pad after mixing and processing, they soon emit unpleasant odors. All sludge aggregates should be carefully removed from the mixing areas as soon as possible.

10. Ponding of rainwater -- When rainwater is allowed to pond on the site, anaerobic decomposition can result and cause unpleasant odors. Therefore, the site must be graded and compost piles located so that no ponding will occur.

HEALTH ASPECTS OF SLUDGE COMPOSTING

Workers at sludge composting facilities encounter disease risks: (a) from the pathogens normally present in sewage sludges, and (b) from fungi and actinomycetes that grow during composting. The former are often referred to as primary pathogens because they can initiate an infection in an apparently healthy individual. The latter are referred to as secondary pathogens because they usually infect only people weakened by a primary infection or by some other trauma such as lung surgery. Densities of secondary pathogens generally are increased by composting. The growth of secondary pathogens is not peculiar to composting sewage sludge but occurs also in many farm and garden operations, such as during the composting of leaves or other materials. Examples of primary and secondary pathogens, along with the diseases they cause, are presented in Table 6.

Studies to define the risk of infection by primary pathogens to people working with sewage wastes are not as extensive as able 6. Examples of pathogens found in or generated during omposting of sewage sludge, together with human diseases ssociated with these pathogens.

RIMARY PATHOGENS

GROUP	EXAMPLE	DISEASE
Bacteria	*Salmonella enteritidis*	Salmonellosis (food poisoning)
Protozoa	*Entamoeba histolytica*	Amoebic dysentery (Bloody diarrhea)
Helminths	*Ascaris lumbricoides*	Ascariasis (worms infecting the intestines)
Viruses	Hepatitis virus	Infectious hepatitis (jaundice)
ECONDARY PATHOGENS		
Fungi	*Aspergillus fumigatus*	Aspergillosis (growth in lungs and other organs)
Actinomycetes	*Micromonospora* spp	Farmer's lung (Allergic response in lung tissue)

ight be desired, but available data indicate that the risk is robably low. The predominant route of infection from the waste aterial is through the mouth. Prevention of infection involves uch precautions as thorough washing of the hands before eating o prevent ingestion of the pathogens. The exposure of workers o primary pathogens in a composting operation is limited to the ile building operation because the temperatures reached in the ext processing step (composting) reduce primary pathogen densities to insignificant levels. The mixing operation presents ittle hazard, because the high moisture levels prevent dust formation.

Medical difficulty from secondary pathogens may result from inhalation of air containing a high density of spores. The probability that individuals in good health will be infected by secondary pathogens encountered in composting is very small. However, people who are predisposed because of such conditions as diabetes, asthma, emphysema, or tuberculosis, or who may be taking such medication as corticosteroids, broad-spectrum antibiotics, or immunosuppressive drugs may be more susceptible to infection.

The help of local medical authorities should be obtained in compiling a medical history questionnaire for work applicants so that predisposed people are screened out. Individuals who are "atopic," i.e., prone to severe allergies, should also be excluded from employment at composting facilities. Moreover, a complete physical examination is recommended, plus inoculations for typhoid, tetanus, and polio.

The following recommendations and provisions are advisable to ensure the health and safety of employees:

1. Rules pertaining to personal cleanliness should be posted in appropriate areas. For example, the following items should be emphasized:

    a. Wash hands before eating, drinking, and smoking.

    b. Wash hands before returning home after work.

    c. Never store food in close proximity to sludge or compost samples taken for analysis.

    d. If accidentally contaminated with sewage sludge or effluent, immediately take a hot shower, and put on clean clothing.

2. Showers and lockers should be provided at the composting facility.

3. The municipality should provide protective clothing, e.g., coveralls and safety shoes for all workers.

4. Workers should change from protective clothing to street clothes at the end of each day. Protective clothing should not be worn home.

5. As necessary, protective clothing should be cleaned and/or sterilized.

6. During periods of dry weather, the area should be sprinkled periodically to ensure that workers do not inhale the dust. During such weather, workers should be encouraged to wear face masks or respirators.

SECTION 4

UTILIZATION OF COMPOST

POTENTIAL MARKETS

The success of a composting operation will depend greatly on the market developed for the product. It is important to appraise the value of the compost for its potential uses; both beneficial and detrimental characteristics should be considered. A realistic evaluation of the potential market relative to the amount of compost produced is especially important. Some municipalities may find it advantageous to distribute compost to consumers at no cost, since this may be a least-cost option to the municipality.

Livestock manures and their composts, peat, topsoil, and chemical fertilizers already hold significant portions of the potential market. There are, however, possibilities for increasing the market by developing new uses.

The potential market can be classified into three broad categories: (1) a very high-profit, but usually small, market for intensive plant culture practices (luxury garden market); (2) a market for restoration of disturbed lands by mixing compost into the unproductive soil of strip mines, gravel pits, road construction sites and areas of urban or suburban development, and (3) a market for use as a fertilizer-soil conditioner for farm crops.

Some promotional effort will be necessary to distribute a steady volume of compost in any of the above markets. Since the cost of composting is very competitive with the cost of alternative disposal practices even with no credit for value of the compost, it will rarely be essential to show a profit on marketing. However, it will be necessary to develop a market sufficient to handle the planned production.

BENEFICIAL EFFECTS AS A FERTILIZER AND SOIL CONDITIONER

Sludge compost applied at a rate to supply the nitrogen requirements of the crop will supply most of the plant nutrients except potassium, thus it may be necessary to apply supplemental potash. However, it is unlikely that sewage sludge composts will be used to supply the total nutrient requirements of agronomic crops because of the large amounts that would have to be applied.

The maximum value is realized when they are employed in combination with inorganic fertilizers; they partly meet the crop's nutrient requirements and also serve as a valuable organic soil conditioner for maintaining soil productivity.

Nearly all of the nitrogen in sewage sludge compost is in the organic form and must be mineralized to inorganic ammonium or nitrate before it is available for crops. Research indicates the compost from the Beltsville Aerated Pile Method mineralizes only about 10% of the organic nitrogen (N) during the first cropping period after the compost is applied. Thus, sludge compost can indeed be considered as a slow-release N fertilizer.

The application of sludge compost alone, at fertilizer rates (i.e., the N requirement of the crop), to marginal soils can produce significantly higher yields than commercial fertilizers applied alone at the same N level. The higher yields are attributed to an improvement in soil physical properties by the compost. Sludge compost is known to improve soil physical properties, as evidenced by enhanced aggregation, increased soil aeration, lower bulk density, less surface crusting, and increased water infiltration, water content, and water retention. Sludge compost added to sandy soils will increase the moisture available to the plant and reduce need for irrigation. In heavy textured clay soils, the added organic matter will increase permeability to water and air, and increase water infiltration into the profile, thereby minimizing surface runoff. The soils also will have a greater water storage capacity. Addition of sludge compost to clay soils has also been shown to reduce compaction (i.e., lower the bulk density) and increase root development and depth.

Large quantities of the sludge compost produced at Beltsville have been mixed with subsoil and used successfully as a topsoil substitute. A number of public agencies, including the National Capital Park Service and the Maryland State Park Service, have used the compost for land reclamation and development research at Beltsville indicates that sewage sludge compost can be used to great advantage in the commercial production and establishment of turfgrasses (Figure 19), trees (Figures 20 and 21), and ornamental plants. Plants and turfgrasses produced with sludge compost were of better quality, had developed more extensive root systems, were transplanted with lower mortality, and were marketable earlier than those grown with inorganic fertilizer alone. It is likely that large amounts of sludge compost will eventually be used on golf courses and cemeteries, and for landscaping the grounds of public buildings.

In addition to the above uses, sludge compost has a major potential for use in the revegetation and reclamation of lands disturbed by surface mining, by removal of topsoil, and by

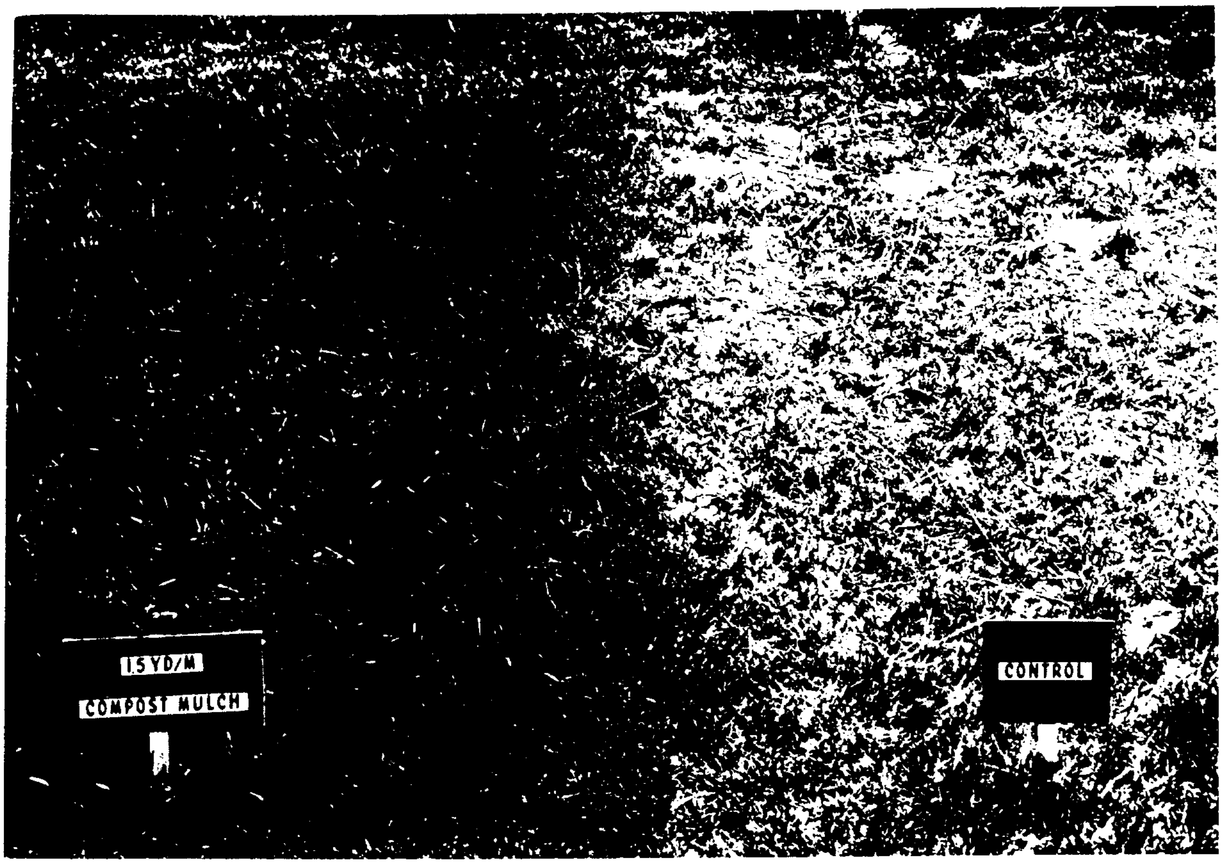


Figure 19. Effect of sludge compost amendment to an infertile soil with clay subsoil on growth of Kentucky bluegrass. Control plot on right received 2 t/1000 sq. ft. of lime, 240 lb/1000 sq. ft. of phosphate, and straw mulch, treated plot on left received 1.5 cu. yd. compost/1000 sq. ft. in addition. Courtesy Dr. Jack Murray, ARS-USDA, Beltsville, Maryland.

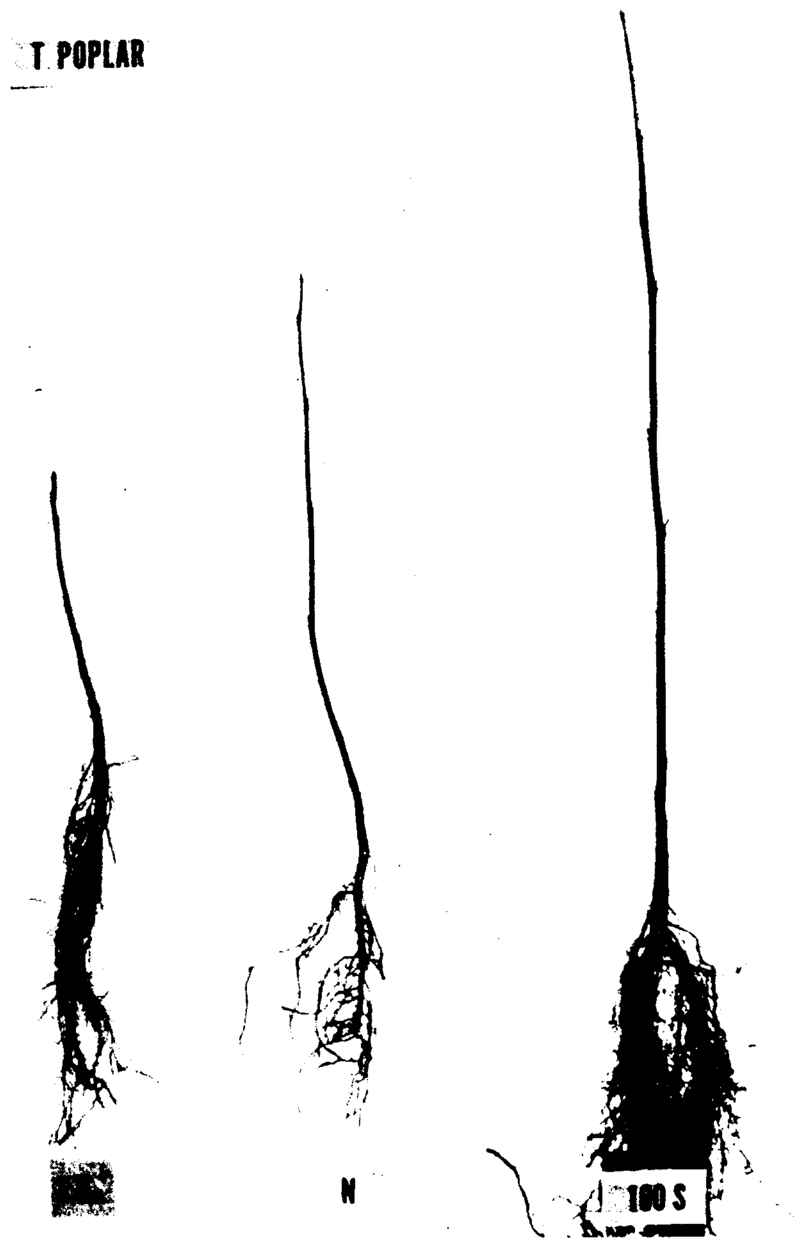


Figure 20. Tulip poplar seedlings showing effects of (N) commercial nursery fertilization; (0) unfertilized control (100 S) 100 T/A screened sludge compost amendment. Courtesty of Frank Gouin, University of Maryland. (See Hort. Sci. 12 (1): 45-47. 1977, for details).

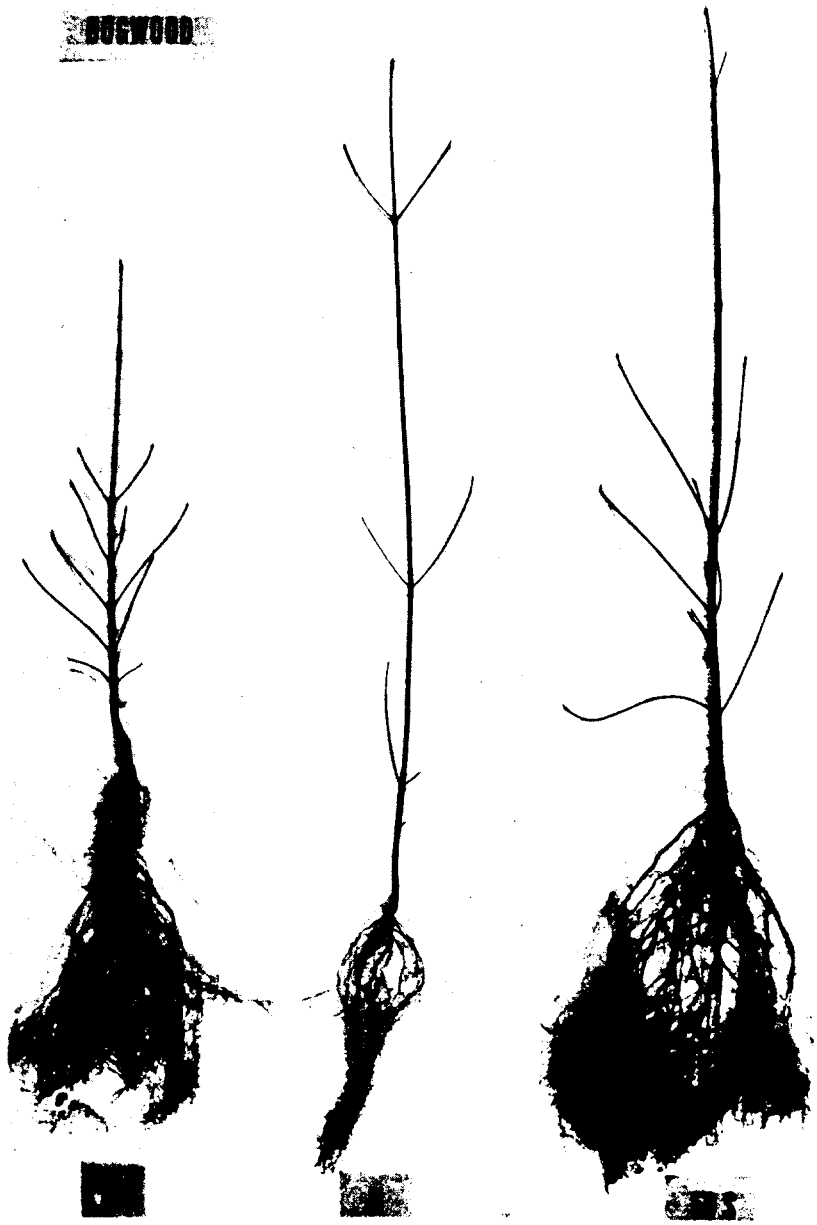


Figure 21. Dogwood seedlings showing effects of (N) commercial nursery fertilization; (0) unfertilized control; (50 S) 50 T/acre sludge compost amendment. Courtesy of Dr. Frank Gouin, University of Maryland. (See Hort. Sci. 12 (1): 45-47. 1977 for details).

excavation of gravel deposits. Eastern stripmined lands are among the most hostile environments for the establishment and growth of plants because of (a) extremely low pH (often below 3.0), (b) extreme droughtiness from lack of organic matter, (c) very high surface temperatures, (d) lack of nutrients, and (e) very poor physical conditions. Research by USDA has shown that through the proper use of sewage sludge compost and dolomitic limestone, a wide variety of agronomic and horticultural crops can be grown on such lands (Figures 22 and 23). With proper management, such disturbed lands can be reclaimed in a surprisingly short time and restored to a high production level.

Recommended compost application rates for various uses to achieve fertilizer benefits and soil improvement are shown in Table 7. In the disturbed soils, higher application rates than listed may be warranted if groundwater contamination is not considered the major factor. For example, if the watershed has little other N inputs and the resulting contamination would be small and/or temporary. Thus, a heavy single application of compost could supply the fertilizer requirements for several seasons. Heavy application rates might also be desirable for disposal purposes during the market development phase of a project.

The fertilizer benefit to the crop from nitrogen contained in the compost may be approximated by appropriate calculations. Several facts must be established to make such calulations:

1. The crop requirement for nitrogen should be estimated. County Agricultural Extension Agents can usually provide nitrogen requirements for crops grown in their particular area, taking into account soil fertility and predicted yield levels.

2. The amount of nitrogen available to the crops during the initial growing season from the applied compost can be estimated as follows:

$$\% \text{ available N} = 0.1 \times \% \text{ organic N}$$

The inorganic N in the compost immediately available to the plant is accounted for in the 10% mineralization rate prediction. Alternatively, the percent mineralizable nitrogen may be determined more accurately by an incubation technique, using the specific soil to which the compost will be added.

3. The amount of nitrogen supplied from the soil (including previously applied compost, crop residues, manures, and chemical fertilizers) should be estimated.

Mineralization of organic N from earlier compost applications will supply a considerable portion of the N requirement along with that which is available from the current application. The second year mineralization of sludge compost is about 5% of

TABLE 7. VARIOUS USES AND APPLICATION RATES OF SEWAGE SLUDGE COMPOST TO ACHIEVE FERTILIZER BENEFITS AND SOIL IMPROVEMENT (ADAPTED FROM HORNICK ET AL 1979)

Use	Compost per 1,000 square feet[1/]	Remarks
	Pounds	
Turfgrasses:		
Establishment:		
Soil incorporated--	2,000-6,000	Incorporate with top 4-6 inches of soil. Use lower rate on relatively fertile soil and higher rate on infertile soil.
Surface mulch-----	600-700	Broadcast uniformly on surface before seeding small seeded species (bluegrass)or after seeding large seeded species (fescues).
Maintenance---------	400-800	Broadcast uniformly on surface On cool-season grasses apply higher rate in fall or lower rate in fall and again in early spring.
Sod production:		
Incorporated -------	3,000-6,000	Incorporate with top 4-6 inches of soil.
Unincorporated-----	6,000-18,000	Apply uniformly to surface. Irrigate for germination and establishment.
Vegetable crops:[2/]		
Establishment-------	1,000-3,000	Rototill into surface 1-2 weeks weeks before planting or in previous fall. Do not exceed recommended crop nitrogen rate.
Maintenance---------	1,000	Rate is for years after initial garden establishment. Rototill into surface 1-2 weeks before planting or in previous fall.
Field crops:[2/]		
Barley, oats, rye wheat-------------	1,000-1,300	Incorporate into soil 1-2 weeks before planting or in previous fall.

TABLE 7 (continued)

Corn	3,000-3,800	Incorporate into soil 1-2 weeks before planting. Supplemental potash may be required depending on soil test.
Legumes[3/]	---	Legumes can be grown in rotation with corn, oats, or other nitrogen-requiring crops.
Forage grasses:		
Establishment	4,000-7,000	Incorporate with top 4-6 inches of soil. Use lower rate on relatively fertile soil and higher rate on infertile soil. Supplement during first year's growth with 1/2 pound per 1,000 square feet (25 pounds per acre) of soluble nitrogen fertilizer when needed.
Maintenance	1,000-1,300	Broadcast uniformly on surface in fall or early spring 1 year after incorporated application.
Nursery crops and ornamentals (shrubs and trees):		
Establishment	1,900-7,000	Incorporate with top 6-8 inches of soil. Do not use where acid-soil plants (azalea, rhododendron, etc.) are to be grown.
Maintenance	200-500	Broadcast uniformly on surface soil. Can be worked into soil or used as a mulch.
Potting mixes	Equal ratio of material[4/]	Thoroughly water and drain mixes several times before planting to prevent salt injury to plants.
Reclamation:		
Conservation planting	Up to 9,200	Incorporate with top 6 inches of soil. Use maximum rate only where excessive growth for several months following establishment is desirable. For each inch beyond 6 inches of incorporation, add 1,000 pounds per 1,000 square feet on soils

TABLE 7 (continued)

		where ground-water nitrogen will not be increased.
Mulch---------------	300-700	Broadcast screened or unscreened compost uniformly on surface after seeding; unscreened is more effective.

1/ 1,500 pounds per 1,000 square feet is equal to 1/2 inch of compost per 1,000 square feet or 33 wet tons per acre based on 40 percent moisture content and 1/2 inch mesh-screened material.

2/ When food crops are grown, careful consideration must be given to the "constraints on uses" described on pages 55 to 59.

3/ Legumes, such as alfalfa and soybeans, do not need all the nitrogen fertilizer supplied by the compost. Maximum benefit of compost as fertilizer can be realized by growing legumes in rotation.

4/ Effective potting mixes have been prepared using equal volumes of sludge compost + peatmoss + vermiculite, compost + peat + sand, or compost + infertile loamy subsoil. After several months' growth, supplemental nitrogen fertilizer may be required.

Figure 22 Response of weeping lovegrass to increasing amounts of sewage sludge compost added to an infertile acid strip-mine spoil.

Figure 23. Scientists examining heavy yield of mixed grasses and legumes grown on infertile acid strip-mine spoil amended with 50 tons per acre of sewage sludge compost.

TABLE 8. AVAILABLE N IN KG FROM A SINGLE APPLICATION OF SLUDGE COMPOST AT INDICATED RATES.*

Sludge Application dry metric tons/ha	Total N Applied (kg)	Available N (kg)		
		1st yr	2nd yr	Subsequent yrs
20	200	20	9	3
40	400	40	18	7
100	1000	100	45	17
200	2000	200	89	34

* Mineralization rates are 10%, 5%, and 2% for the first, second, and subsequent years, respectively.

the remaining organic N and it is estimated that 2% of the remaining organic N will mineralize per year after the second year. Table 8 contains the available N levels for a designated application of compost containing 1.0% organic N. If a user were to use compost only as the N source for his crop and the crop required 100 kg N/ha, he would apply 100 metric tons/ha the first year, about 60 metric tons/ha the second, third and fourth years, and 30 metric tons/ha thereafter until a mineralization equilibrium would be established; at that time, the amount of available N would equal the total N applied. The number of years of successive compost applications required to reach equilibrium has not yet been established by research. The user might also consider supplementing nitrogen needs with fertilizer, depending on availability and cost. The user should be aware that, in addition to N availability, heavy metal and salt accumulation will also be factors in the determination of a beneficial cumulative loading rate for sludge compost.

In potting soil mixes, sludge compost can supply organic matter, the macronutrients nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and iron (Fe), and the micronutrients copper (Cu), zinc (Zn), manganese (Mn), molybdenum (Mo), and boron (B). In such mixes, it can be used in various combinations with peat-vermiculite, peat-sand, and mixed with infertile subsoil. To ensure optimum plant growth, some inorganic N fertilizer and potassium may have to be applied.

Use of high rates (>50% by volume) is wasteful of the nutrients in the sludge compost, and can cause salt toxicity. Leaching of the mix during watering, a normal horticultural practice, removes excessive soluble salts. A very successful potting mix developed at Beltsville consists of equal parts by volume of compost, peat, and vermiculite. With this mix, no salt problems occurred during the growth of several crops (watered to achieve leaching). However, some additional nitrogen was needed after 4 weeks of growth.

CONSTRAINTS ON USES

Pathogens Because of its origin, compost made from sewage sludge may not be readily accepted by the public from the standpoint of esthetic or health aspects. Esthetic reservations will generally be dispelled upon direct examination of the compost itself, which the observer will perceive as being free from offensive odors and having the appearance of a highly fertile soil. Reassurance on health safety may depend more on an explanation of the composting process and the high temperature disinfection involved, reinforced perhaps by approval from local health authorities. If composting is properly done, as described in this manual, it destroys or reduces to insignificant levels all primary pathogens present in sewage sludges. Once destroyed, viruses, helminths, protozoans, and most bacteria will not repopulate the compost, since they cannot grow external to their hosts. Salmonella, one of the most common organisms causing food poisoning, can regrow to a limited extent in the finished compost, but it does not compete well with other microorganisms present.

Salmonella bacteria are frequently found in the environment. They are often present in fecal material of wild and domestic birds and animals, including pets, and have been isolated from streams and vegetation of mountainous areas remote from human population centers. No significant hazard should be associated with their presence in compost so long as the compost does not come into contact with food.

Heavy metals Many sewage sludges contain large amounts of heavy metals which may reduce the value as a fertilizer for either direct application to land or for composting. Excessive amounts of these metals are often found in sludges where industrial effluent is discharged into the sanitary sewers without pretreatment. Application of high metal sludges on land results in soil enrichment in heavy metals. Experiments on sludge application have shown that soil enrichment by zinc, copper, and nickel can cause direct phytotoxic effects manifested as decreased growth and yield, especially where soil pH is low (pH 5.5) and rates of application are high. Heavy metals may also accumulate in plant tissues and enter the food chain through direct ingestion by humans or indirectly through animals.

The element of greatest concern to human health where sewage sludges and sludge composts are applied to land is cadmium (Cd), since it is readily absorbed by most crops and is not generally phytotoxic at the concentrations normally encountered. Therefore, Cd can accumulate in plants and enter the food chain more readily than, for example, lead (Pb) or mercury (Hg), which are not readily absorbed and translocated to the edible portion of crops. However, since Hg is accumulated by mushrooms, sludge compost should not be used for mushroom culture. Most human exposure to Cd comes from food (principally grain products, vegetables, and fruits) and results in an accumulation of the element in the liver and kidneys. Approximately 3 to 5 percent of dietary Cd is retained by humans. If dietary Cd is substantially increased over long periods of time, Cd can accumulate to levels that might be expected to cause kidney injury. Among the sources that contribute to the level of Cd in food are (a) soils and surface waters contaminated by disposal of wastes, (b) soils inherently high in Cd because of geochemical factors, (c) industrial fallout, and (d) phosphatic fertilizers containing Cd, and (e) industrial contamination of soil and/or food.

The World Health Organization (WHO) has recommended that the maximum level of dietary Cd should not exceed 70 μg/person/day. Workers in the U.S. Food and Drug Administration (FDA) advance the view that any further increase in dietary intake of Cd seems undesirable. However, the extent of the hazard is debated because current data are incomplete about human exposure to Cd and risk through their lifetime. Thus, in order to limit this risk, the utilization of organic wastes on land is restricted by regulatory agencies to control the level of Cd in food chain crops.

Plant species, as well as varieties, have been found to differ markedly in their ability to absorb and translocate heavy metals, to accumulate them within edible organs of the plant, and to resist their phytotoxic effects. Leafy vegetables are usually sensitive to the toxic effects of metals and accumulate them; cereal grains, corn, and soybeans are less sensitive; and grasses are relatively tolerant. Uptake studies with corn, soybean, and cereal grains have shown that heavy metals accumulate less in the edible grain than in the leaves; similar results are found for edible roots, as radish, turnip, carrot, and potato, and fruits, as tomato, squash, etc.

The availability to and uptake of heavy metals by plants are influenced by certain chemical and physical properties of soil, especially pH, organic matter content, cation exchange capacity (CEC), and texture (i.e., the proportions of sand, silt, and clay). Phytotoxicity and plant availability of sludge-borne metals are higher in acid soils than in those with neutral or alkaline pH. Maintaining soil pH in the range of 6.5 or above by liming reduces the availability of heavy metals to plants. Application of organic amendments such as manures and crop residues can also decrease the availability of heavy metals to plants. The CEC is a measure of the soil's capacity to retain cations; higher CEC is usually associated with higher clay and organic matter contents. Heavy metals are generally less available to plants in soils of high CEC (e.g., organic matter rich soils or clay loams) compared with soils of low CEC (e.g., loamy sands). Recent research at Beltsville suggests that, on a total metal basis, heavy metals are less available to plants in composted sewage sludges than in uncomposted raw and digested sludges, although the reason for this is not yet known.

The metal contents of digested sewage sludge in terms of the range of observed levels, the maximum levels recommended for landspreading and the median levels found in several surveys are presented in Table 9. The levels of heavy metals for raw or undigested sewage sludges would be approximately one-half of those shown in the table, since anaerobic digestion reduces the volatile solids and thus tends to increase the metal content. In the view of the present writers, the Cd/Zn ratio of sludges used on cropland should not exceed 0.015; that is, the Cd content of sewage sludge should not exceed 1.5 percent of the zinc content. The reasons for this are as follows: a) if Zn levels in the soil are much higher than Cd, plant Zn will accumulate to phytotoxic levels before sufficient Cd can be absorbed to endanger the food chain, b) Zn reduces absorption of Cd in animal intestines, and c) Zn inhibits uptake of Cd by dicotyledonous plants at low Cd/Zn ratios. Limited experimental evidence has shown a low Cd/Zn ratio reduces potential impact of soil Cd when soil pH drops below the recommended limits, while cumulative Cd application limits control Cd effects at pH 6.5 or above. At present, regulation of Cd/Zn ratio is not universally accepted, but no other method has been proposed which limits impact of Cd in acid soils.

Median sludge Cd was 13 or 16 ppm, and Cd/Zn $\geq$ 1%. Metal contents indicated in Table 9 as "Typical Domestic Level" are achieved by many large cities in the United States, e.g. Washington, D.C., Baltimore, MD, Denver, CO, and Philadelphia, PA. Sludge metal contents in cities with higher levels could be reduced by industrial pretreatment. It has not yet been shown that pretreatment will produce acceptable sludge metal levels at all locations, although most evidence supports pretreatment.

To limit the buildup of heavy metals on agricultural land resulting from the landspreading of either sewage sludges or sludge composts, USDA proposed certain recommendations in 1976. Two categories of land were delineated: (1) privately owned land and (2) publicly owned or leased land dedicated to sludge application. (Copies of the draft document are available from the Office of Environmental Quality Activities, USDA, Washington, D.C.). Such recommendations hopefully will encourage the use of sludges of low heavy metal content for composting and direct land application on privately owned land. The recommendations were based on the best information available at the time from scientists at a number of state universities and agricultural experiment stations, as well as from USDA sources.

TABLE 9. METAL CONTENT OF SEWAGE SLUDGE BASED ON SEVERAL SURVEYS.

Element	Maximum[1/] Domestic	NC-118[2/] Median	Mean	Range	Northeast[3/] Median	Mean	Range
Cd, ppm	25	16	110	3- 3410	13	72	0.6 - 970
Zn, ppm	2500	1740	2790	101-27800	1430	2010	228 -6430
Cd/Zn, %	1.0	1.0	4.8	0.1-100	0.84	3.64	0.26- 78
Cu, ppm	1000	850	1210	84-10400	790	1080	240 -3490
Ni, ppm	200	82	320	2- 3520	42	129	10 -1260
Pb, ppm	1000	500	1360	13-19700	500	735	52 -4900

1/ Digested sludge, Chaney and Giordano, 1977.

2/ 169-208 sludges, Sommers, L. E. 1977. Chemical composition of sewage sludges and analysis of their potential use as fertilizers. J. Environ. Qual. 6(2):225-232.

3/ 43 treatment plants, (digested sludge), Chaney, R. L., S. B. Hornick, and P. W. Simon. 1977. Heavy metal relationships during land utilization of sewage sludge in the Northeast. p. 283-314. In R. C. Loehr. (Ed.). Land as a waste management alternative. Ann Arbor Science Publishers, Inc., Ann Arbor, Mi.

Table 10 shows the recommended maximum cumulative sludge metal loadings for privately owned agricultural land according to the soil cation exchange capacity (USDA recommendations). Soils in the 0 to 5 CEC range are characteristically sands through sandy loams; the 5 to 15 range includes sandy loams, loams, silt loams; and > 15 includes silty clay loams and clays. Higher metal loadings would be considered reasonably allowable on heavier textured soils. Cadmium loadings on land should not exceed 2 kg/ha/year for dewatered sludge or sludge compost and should not exceed the total cumulative loadings shown in Table 10. When sludges are applied, the soil should be limed to pH 6.5 and maintained at 6.2 or higher. Sludges and sludge composts should not be applied to land used to grow tobacco as this crop allows high transfer of Cd to humans; sludges and composts used on land used to grow leafy vegetables should be low in Cd and Cd/Zn ratio to minimize any effects on humans.

On publicly controlled land, a maximum of up to 5 times the amount of sludge-borne metals listed in Table 10 seems to represent a reasonable limit if the sludge is incorporated into the soil to a depth of 15 cm. With deeper incorporation, total metal applications may be proportionally higher. These metal loadings are permissible only when the pH is maintained at pH $\geq$ 6.5; cropping with Cd-excluding grains (e.g. corn) minimizes the impact of this practice.

TABLE 10. RECOMMENDED MAXIMUM CUMULATIVE METAL LOADINGS FROM SLUDGE OR SLUDGE COMPOST APPLICATIONS TO PRIVATELY OWNED LAND.

Metal	Soil cation exchange capacity (meq/100g) 1/		
	0 - 5	5 - 15	>15
	(Maximum metal addition, kg/ha)		
Zn	250	500	1000
Cu	125	250	500
Ni	50	100	200
Cd	5	10	20
Pb	500	1000	2000

1/ CEC determined prior to sludge application using 1 N neutral ammonium acetate and is expressed here as a weighted average for a depth of 50 cm.

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APPENDIX

ANALYTICAL METHODS

A compendium of analytical methods for sewage sludges and sludge composts has not yet been published. Nevertheless, a number of references are available which will be helpful in the chemical and microbiological analyses of these materials. These are listed as follows:

a. A Manual of Methods for Chemical Analysis of Water and Wastes. 1974. (EPA-625-16-74-003).

b. Standard Methods for the Examination of Water and Wastewater--Including Bottom Sediments and Sludges. 1975. 14th edition, published jointly by the American Public Health Association, the American Water Works Association, and the Water Pollution Control Federation. Available from the American Public Health Association, 1790 Broadway, New York, N.Y.

c. Sampling and Analysis of Soils, Plants, Wastewaters, and Sludge: Suggested Standardization and Methodology. 1976. North Central Regional Publ. No. 230. Available from Kansas State University Agricultural Experiment Station, Manhattan, Kansas. 20 p.

d. Methods of Soil Analysis. 1965. Part I: Physical and Mineralogical Properties, including Statistics of Measurements and Sampling. Agronomy J. No. 9, American Society of Agronomy, Inc., Madison, Wisconsin. 768 p.

e. Methods of Soil Analysis. 1965. Part II: Chemical and Microbiological Properties. Agronomy J. No. 9, American Society of Agronomy, Inc., Madison, Wisconsin. p. 768-1569.

f. Recommended Procedure for the Isolation of Salmonella Organisms from Animal Feeds and Feed Ingredients. Agricultural Research Service, U.S. Department of Agriculture. ARS 91-68-1, July 1971. 15 p.

Methods generally accepted for analyzing components needed in calculating compost application rates are: total N by Kjeldahl;

NH_4-N by analysis of NH_4 in the filtrate of an extract of 1 g of sludge or compost with 50 ml of 2N KCl for 60 minutes; total P, K, Ca, Mg, Zn, Cu, Ni, Cd, Pb, and Fe in a dry-ashed or wet-ashed sample using colorimetric or atomic absorption analysis (atomic absorption is the preferred method, especially for important elements like Cd, but background correction is required for analysis of Cd, Ni, and Pb by this method). If Hg, Se, or As analyses are needed, only wet ashing is acceptable; for Hg analyses, a wet sample should be used, as heat drying (105°C oven) causes volatilization of Hg. $CaCO_3$ is measured by consumption of acid using a pH meter titration method; soluble salts are measured as conductivity of the saturated extract.

A plant germination and early growth test in which a mix of compost soil is used at a typical loading rate ($\leq$ 50 T/ha) and compared to a control will demonstrate whether improper composting, or the salts, introduced with the compost could interfere with planned uses. Customarily, seeds of several species (corn, bean, cucumber) are sown; percent germination and growth patterns are observed.

MONITORING EQUIPMENT

Note: All equipment with exception of pH meter should be portable and rugged.

Temperature reading devices: Must have temperature range of at least 0°C to 100°C. Probe should be 1.5 meters long for insertion into compost pile. Some typical equipment is listed below:

1. Thermistemp Tele-thermometers--Yellow Springs Instruments, Model 42. (Available through Fisher Scientific or Curtis-Matheson Scientific). General purpose, with three overlapping scales to continuously monitor temperature in range from -40°C to 150°C. Probe to be used with this instrument listed below.

2. Thermistor probe. Atkins Technical Inc., Model PK-35. To be used with above Tele-thermometers. General purpose and moderately heavy duty.

3. Compact, portable, temperature-calibrated potentiometer. James G. Biddle Co., Cat. Nos. 606115 and 604116, Leeds and Northrup. Suited for making accurate temperature measurements from thermocouples, checking and measuring thermocouples, as well as checking other thermocouple pyrometers, recorders, and controllers.

4. Insulated thermocouple wire--Fisher Scientific, Leeds and Northrup Co. 16-gauge wire capable of handling

temperatures up to 195°F (90°C) used.

Oxygen reading devices

1. Portable oxygen analyzer--Teledyne Analytical Instruments Model 320 B/RC, Taylor Servomex Type OA 250. Used in field or laboratory situation for instant O_2 determination in air medium. A probe for collecting gas samples for analysis may be made from 0.6-cm steel tubing. The tube is capped or pinched off and small holes are drilled near the tip.

Moisture content determination devices

1. Moisture determination balance--Ohaus Model Nos. 6109, Mettler Model LP 11. Combination balance and heat lamp for taking original weight, drying out sample, and taking final weight. The instrument is calibrated to read in percent moisture content.

Air velocity determination devices

1. Thermo-anemometer and probe -- Alnor Instrument Co., Type D 500 K. For use in determining air flow velocity in pipe. Range from 10 to 2000 feet per minute. Portable, for field use.

Pressure determination device

1. Magnehelic pressure gauges--Dwyer Instruments Inc. Portable, for measuring pressure in pipe flow in field or laboratory. Can be obtained to cover various ranges and pressures.

pH determination devices

Compost is prepared for analysis by making a slurry with distilled water (1:1) and allowing slurry to stand for 30 minutes before the determination. Many suitable pH meters are available, two are listed below:

1. Laboratory expanded scale research pH meter--Fisher "Accumet" Model 320, Corning Model 110 (Digital) Scientific. For use in laboratory situation. Models vary in type of readout and precision.

2. pH meter, pocket size, analytical--VWR Scientific. For on the spot readings in the field. Completely self-contained in waterproof carrying case.

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/8-80-022	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE MANUAL FOR COMPOSTING SEWAGE SLUDGE BY THE BELTSVILLE AERATED-PILE METHOD		5. REPORT DATE May 1980 (Issuing Date) 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) G. B. Willson, J. F. Parr, E. Epstein, P. B. Marsh, R. L. Chaney, D. Colacicco, W. D. Burge, L. J. Sikora, C. F. Tester, S. Hornick		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS U. S. Department of Agriculture Beltsville, Maryland 20705		10. PROGRAM ELEMENT NO. C36B1C 11. CONTRACT/GRANT NO. S803468
12. SPONSORING AGENCY NAME AND ADDRESS Municipal Environmental Research Laboratory-Cin., OH Office of Research and Development U. S. Environmental Protection Agency Cincinnati, Ohio 45268		13. TYPE OF REPORT AND PERIOD COVERED Final 14. SPONSORING AGENCY CODE EPA/600/14

15. SUPPLEMENTARY NOTES

Project Officer: James A. Ryan (513) 684-7653

16. ABSTRACT

In producing clean water from sewage, wastewater treatment plants also produce sludge. Most of the commonly used methods to dispose of this material are now considered to be either environmentally unacceptable, wasteful of energy, or very expensive. To ease this situation, a relatively simple, rapid, and inexpensive sludge composting process has been developed at Beltsville. The method makes possible the conversion of undigested sludge into a composted product that is aesthetically acceptable and meets environmental standards. The material has demonstrated usefulness as a soil amendment stimulative to plant growth. If relatively simple control procedures are followed, the compost appears to be free of primary human pathogens because of the lethal effect of heat generated during the composting process on such organisms.

The new Beltsville composting procedure, detailed here in respect to both prinples and practice, represents a major advance over previously known composting methods It is adaptable to practical use in municipalities of widely varying size. In many situations its short startup time will allow its use as an emergency interim solution for sludge management. Key information is presented on the economics of the process, and on the marketing and use of the product as a soil conditioner to improve plant growth.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Aerobic processes Sewage disposal Composts	Beltsville static-pile composting Agronomic utilization of sewage compost	13B 6D 2A

18. DISTRIBUTION STATEMENT RELEASE TO PUBLIC	19. SECURITY CLASS *(This Report)* UNCLASSIFIED 20. SECURITY CLASS *(This page)* UNCLASSIFIED	21. NO. OF PAGES 81 22. PRICE

EPA Form 2220-1 (9-73)

☆ U.S. GOVERNMENT PRINTING OFFICE 1980-657-146/5649

Compost operation on hold until renovations done

BY CAROL COMEGNO • COURIER-POST STAFF • AUGUST 23, 2008

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MOUNT HOLLY — Burlington County shut down its compost operation this week at its Florence resource recovery complex to make $3.8 million in improvements for the next several months.

Mary Pat Robbie, director of the county department of resource conservation, said municipal sewage treatment plants can continue to send sewage sludge solids to the county in the meantime.

Sludge is mixed with with wood chips inside bins and decomposes through aging and aeration to create garden compost that is marketed to landscape companies and to soil manufacturers in New Jersey and surrounding states.

While the 10-year-old plant is closed for its first renovation into November,the state Department of Environmental Protection is allowing the county to dump sludge temporarily into the adjacent county landfill in Mansfield, Robbie said.

She said repairs to the structural steel and to the roof are needed because of moisture problems caused mainly by a fire suppression system that the state originally required the county to install.

Meanwhile, a new operator will take over the composting Sept. 15 at a cost savings to the county.

The county last week awarded a 10-year, $10 million base contract to WeCare Organics of Jordan, N.Y.

Freeholder William Haines Jr. said that will save a projected $7.4 million over that time period because the cost is much lower than what the present operator is charging.

The operator can sell all of the compost but must give the county 20 percent of the income generated from sales, according to the new contract.

Robbie said the new management contract price is less because the new contractor expects to be able to bring sludge in from other counties and make more compost to sell.

In a request-for-proposal process, WeCare's price was $700,000 a year cheaper than the current

Photo provided

Burlington County shut down its compost operation this week at its Florence resource recovery complex.

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contractor, Synegro of Houston, Tex.

A third company also bid higher.

"The freeholders and the county's project review team that reviewed the proposals are confident that WeCare is capable of efficient operation of the co-composting facility and of compliance with environmental regulations," Haines said.

Jeff LeBlanc, WeCare's president, was formerly employed by the company that designed and built the plant and was instrumental in preparing it to begin operation in 1998.

Robbie said the base contract price of $1 million a year will increase yearly at the inflation rate of the consumer price index.

Reach Carol Comegno at (609) 267-9486 or ccomegno@courierpostonline.com

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Mitsubishi Corporation

Slurry Carbonization is the key to turning [waste] into a high-energy fuel

Chemical Engineering Magazine

Both a product [clean fuel] and a service [waste disposal] ... that could provide a cost effective solution to a key environmentally-related problem

National Institute of Standards and Technology

What is the SlurryCarb™ Process?

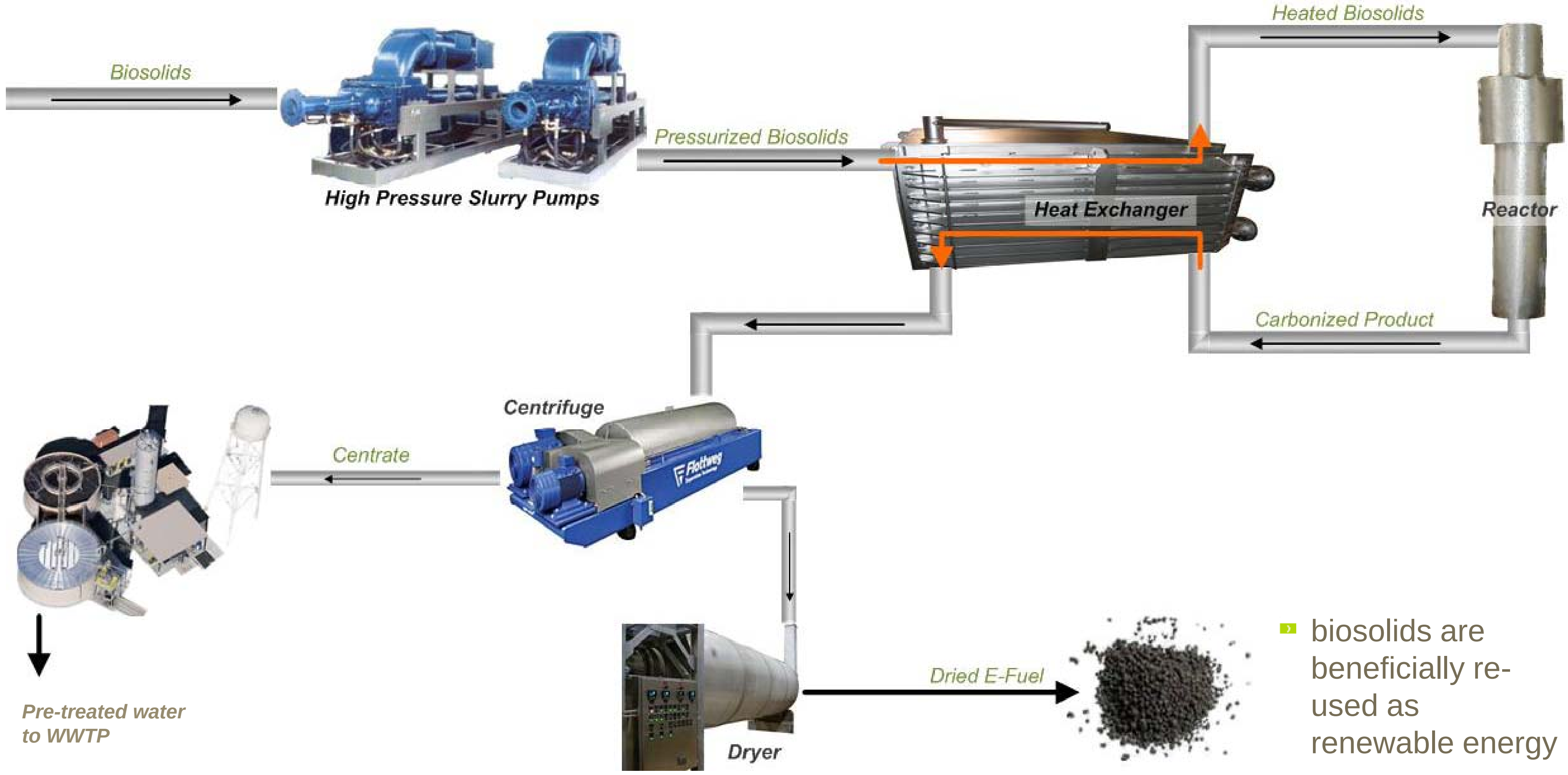
- The SlurryCarb™ process is a patented technology that converts biosolids (sewage sludge) and other high moisture organic feedstocks into a renewable fuel called E-Fuel
- The process provides a new option for biosolids management in three ways:
    1. recycling the energy content inherent in biosolids
    2. producing renewable energy
    3. Making possible 100% beneficial reuse of biosolids
- SlurryCarb™ is an efficient and environmentally sound alternative to current biosolids management options

Renewable Energy From Biosolids

How does the SlurryCarb™ process work?

- Biosolids are subjected to pressure and heat
- Upon reaching the desired reaction temperature, the biosolids break down into carbon and light gases
- The result is a slurry with molecules that are much smaller than the original biosolids and very high in energy
- Excess moisture is then extracted from the slurry
- The end product, a renewable fuel called E-Fuel, is an alternative to fossil fuels

The SlurryCarb™ Process



- biosolids are beneficially re-used as renewable energy

SlurryCarb™ Process Performance

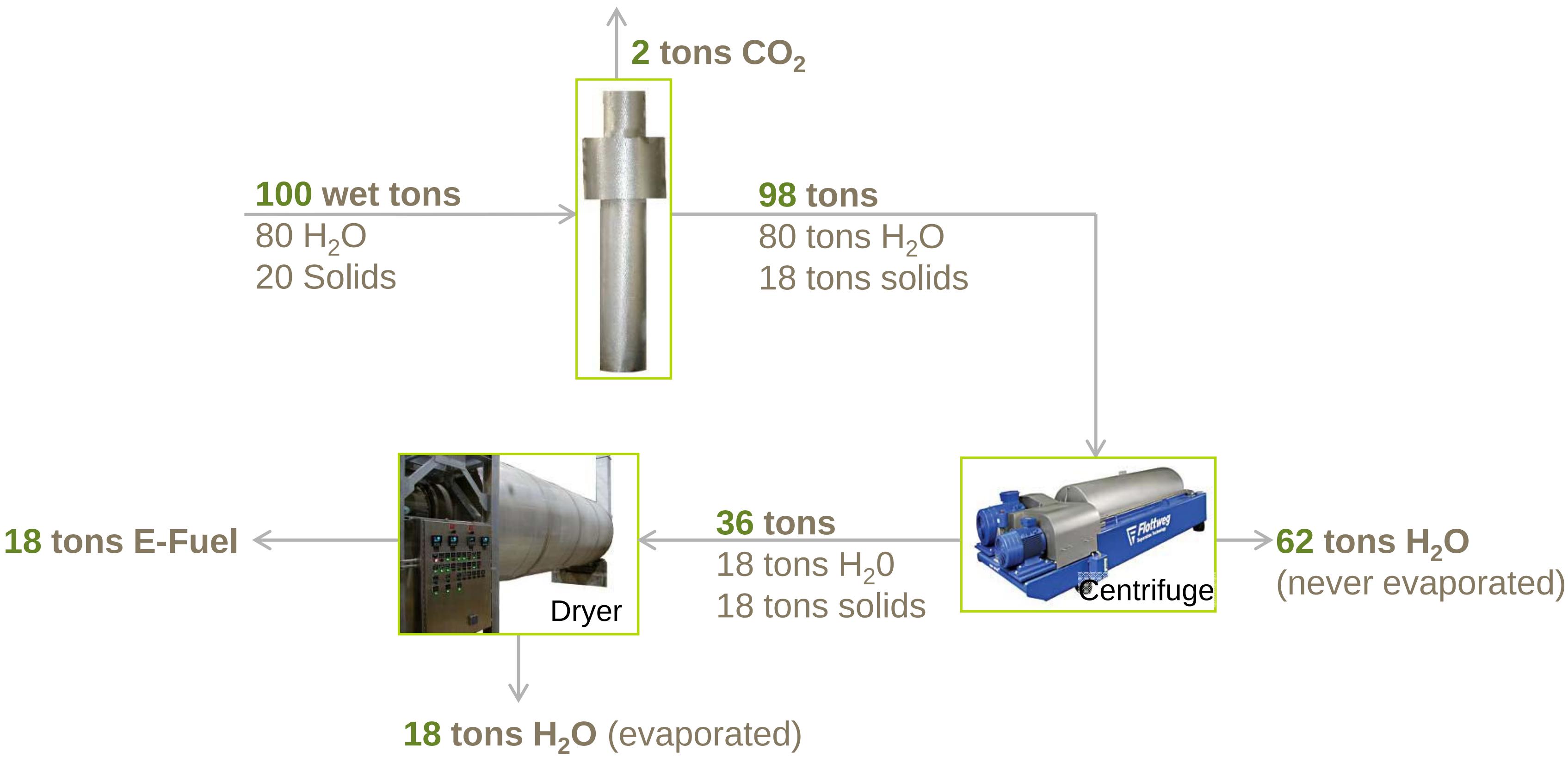
- A SlurryCarb™ facility can receive biosolids at 15 to 30 percent solids
- Process reaction time is approximately 10 minutes
- Reacted product is mechanically dewatered to greater than 50% solids
- Using biosolids, the process produces a 6,500-8,000 Btu/lb E-Fuel
- E-Fuel has combustion characteristics similar to coal
- Process produces more energy than it consumes

SlurryCarb™ Advantages

- Long-term, predictable cost
- Reclaim land utilized for biosolids disposal
- Reduced chemical costs
- Reduced operating costs
- Reduced energy costs
- Regional facilities reduce trucking costs

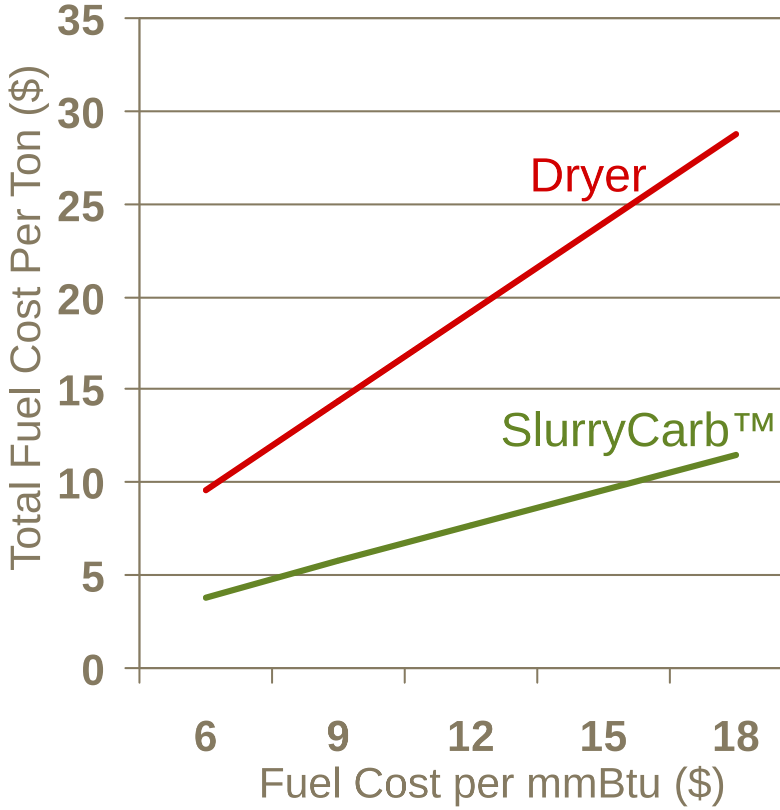
Simple Mass Balance for SlurryCarb™

SlurryCarb™ consumes approximately two thirds less energy than drying



Hedge Against Fuel Cost Risk

SlurryCarb™ Fuel Cost Savings



Assumes 80% $H_2$0 biosolids

Energy Consumption: SlurryCarb™ vs. Drying

	H_2O Evaporated	**Total Energy**
Drying	80 tons	160,000,000 Btu
SlurryCarb	18 tons	64,000,000 Btu

Assumes 100 tons of biosolids at 80% $H_2$0

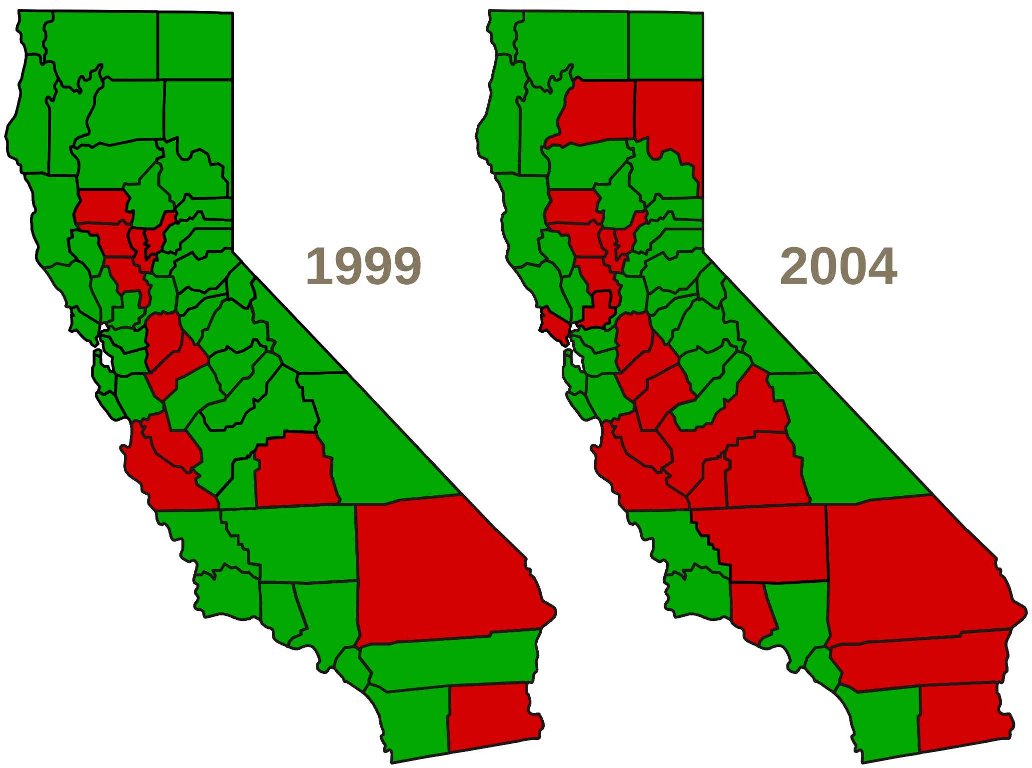
SlurryCarb™ Facilities

Summary:
Why the SlurryCarb™ Process?

- Process is a net energy producer (Environmentally friendly)
- Provides a sustainable biosolids management solution (Cost-effective)
- Converts organic material into carbon by accelerating Mother Nature's method (Proven)
- Produces renewable energy from biosolids (A green technology)
- Most major equipment is off-the-shelf (Simple)
- Design complete (Ready to go)
- Extensively patented (Innovative technology)

Diminishing Capacity

California Land Application: county bans are spreading



Source: OCSD

E-Fuel: *the product*

- E-Fuel has 6,500-8,000 Btu/lb in dry form
- Suitable for gasification, co-firing, use in cement kilns or utilization in industrial and utility boilers
- Produces approximately 1 MWH per ton
- Minimizes fossil fuel consumption
- Produces essentially zero net greenhouse gas emissions

E-Fuel

E-Fuel vs. Fossil Fuels

Fossil Fuels	E-Fuel
Burning fossil fuels releases ancient carbon that has been sequestered in the earth for millions of years	E-Fuel utilizes carbon that is sequestered by living plants and human-generated waste, and is part of the recent Carbon Cycle
Use of fossil fuels depletes natural resources that take thousands of years to replenish	Waste is a readily renewable resource, resulting in an endless supply of E-Fuel
Fossil fuel use causes a rise in greenhouse gas emissions and contributes to global warming	E-Fuel recycles CO_2 and produces essentially zero net greenhouse gas emissions

Renewable Standard

Pre-Certified Eligible for California's
Renewable Portfolio Standard
and for Supplemental Energy Payments

This is to certify that

EnerTech Rialto Biopower

Located in : Bloomington, CA
Owned by: EnerTech Environmental, Inc.

*Has been pre-certified by the California Energy Commission as eligible for California's Renewable Portfolio Standard and for Supplemental Energy payments under the criteria established in the **Renewables Portfolio Standard Eligibility Guidebook,** publication number 500-04-002F1, adopted August 2004, and the **New Renewable Facilities Guidebook,** publication number 500-04-001F, adopted May 2004, and assigned CEC-ID number:*

60491D

INFORMATION SUBMITTED FOR PRECERTIFICATION SUBJECT TO FURTHER VERIFICATION WHEN PROJECT IS COMPLETED AND BEGINS COMMERCIAL OPERATIONS.

Authorized Signature

February 27, 2006
Date Issued

CERTIFICATION VALID UNTIL JANUARY 1, 2009

E-Fuel is certified as a renewable fuel in the State of California.

EnerTech Environmental, Inc.

NEWS

Bob Keefe
COX NEWSPAPERS

(enlarge photo)

Kevin Bolin is president and CEO of Atlanta-based EnerTech Environmental Inc. The company's plant in Rialto, Calif., is expected to start converting sewage sludge into fuel by the end of the year. 'What we're doing is basically addressing a problem in need of a technical solution,' Bolin said.

ENERGY

Experimental plant turns poop to power

Company is working on the next new energy source: fuel from human waste.

By **Bob Keefe**
WEST COAST BUREAU

Monday, July 07, 2008

RIALTO, Calif. — At the end of a dusty dirt road, next to a cement factory and a junkyard, an Atlanta company is working on the next new energy source: fuel from human waste.

By the end of the year, the $160 million plant that EnerTech Environmental Inc. is building in this community east of Los Angeles is expected to take hundreds of tons of sewage sludge — which isn't only treated human waste, but is anything and everything that passes through the drain — from local sanitation districts. The plant will process the sludge with a mixture of high heat and high pressure, turning it into a pelletlike substance dubbed "e-fuel" that can run small power plants.

The poop-to-power process is the brainchild of former Atlanta ad man Kevin Bolin and his grandfather, 92-year-old Norman Dickinson of Melbourne, Fla.

In addition to being a former chemical engineer, "my grandfather is kind of a mad inventor," said Bolin, 45.

A former accountant and advertising executive for Atlanta TV station WAGA-TV, Bolin is fluent in the workings of effluent and sharp in the ways of finance and business.

"It was really a dream of mine to help form a company and commercialize some of these inventions," he said.

Although untested on such a large scale, the project is getting accolades from local officials and investors who say it could become a viable way to address high energy costs while simultaneously relieving overburdened sanitation systems.

"This stuff comes to us seven days a week, 24 hours a day," said Ed Torres, director of technical services for the Orange County Sanitation District, one of five Southern California sewage systems that have signed on with the EnerTech plant. "We can't just turn the valve off. We have to do something with it."

Orange County and other local sanitation districts currently dispose of their sludge mainly by trucking it to farms — some of them hundreds of miles away in Arizona — where it fertilizes livestock feed crops or inedible plants.

Tougher environmental regulations and high diesel fuel costs,

approach to restaurant business

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however, are making that practice increasingly prohibitive.

The five Southern California sanitation districts have agreed to pay EnerTech $390 million for taking about 670 tons of sewage sludge per day for the next 25 years.

"In the past, that might have been fairly expensive," said Mike Sullivan, supervising engineer for the Los Angeles County Sanitation District, another participant. "But with other alternatives disappearing and the cost of diesel fuel rising, it's becoming much more" attractive.

Getting paid to process the smelly sludge will generate about 97 percent of EnerTech's revenue, Bolin said. He expects the other 3 percent to come from selling the e-fuel, first to local cement kilns and other businesses that run their own power plants and perhaps eventually to utilities.

Bolin said the fuel generates about the same amount of energy per pound as coal but is cleaner in terms of carbon emissions. As with other renewable fuels, EnerTech's e-fuel emits only the carbon dioxide that is already contained in the unprocessed sludge when it is burned. By contrast, fossil fuels such as coal or oil release carbon that has been stored and naturally sequestered for millions of years when they are burned. Therefore, EnerTech says, there is no significant net increase in carbon dioxide emissions with e-fuel, unlike fossil fuels.

The State of California has certified e-fuel as a renewable fuel, and local air-quality regulators have issued a permit for EnerTech's processing plant.

"What we're doing is basically addressing a problem in need of a technical solution," Bolin said. "We're converting a waste — sludge — into something that's beneficial."

Bolin and his grandfather aren't the only ones betting big on the idea. In April 2007, the company raised $160 million to start construction on the Rialto plant through the sale of bonds to Deutsche Bank. This year, it raised an additional $42 million from investors, including Citigroup Inc. and the Masdar Clean Tech Fund, a United Arab Emirates venture fund.

In May, EnerTech was selected to build a small demonstration plant in Masdar City, a first-of-its-kind city being built in the United Arab Emirates that will use only renewable energy.

"Investing in EnerTech Environmental is a key part of the overall Masdar ambition," Alex O'Cinneide, a partner in the Masdar Clean Tech Fund, said in a statement. "Their innovative technology is the kind of smart clean technology that has the potential to alter the way developers consider future projects."

This isn't the first time that someone has tried to turn sludge into something more beneficial. In states across the country, including Texas, cities operate sludge incineration plants that produce power or ash that can be used as fertilizer.

About two decades ago, officials spent hundreds of millions of dollars on a sludge-processing operation in Los Angeles that was designed to do exactly what EnerTech's plant is supposed to do: turn sludge into fuel. However, that project failed.

Bolin is quick to point out that EnerTech's project is much different. The so-called Carver-Greenfield project used oil and forced evaporation to separate biosolids from sludge, but the process gummed up pipelines and ultimately shut down the system.

"It was much more complicated," said Bolin, who wasn't involved with that project. "We dumbed it down into what's actually a very simple process."

Through a system of pipes and tanks, EnerTech's plant will essentially heat up and pressurize biosolids to the point where they break down. The resulting mushy "slurry" mixture is dried and turned into e-fuel.

Still, nobody is sure that EnerTech's "SlurryCarb" process will work on the scale planned in Rialto. The company has tested the process only with much smaller demonstration plants in Atlanta and Japan, tests that Bolin says worked better than expected.

Officials in California say they aren't too worried about the plant's prospects, especially because — unlike with the project 20 years ago — they do not have any money at risk upfront.

"We're all hoping it works, but at this scale it's never been proven," Torres said. "But at least here, we're not investing a dime. If it doesn't work, we'll just go someplace else" with the sludge.

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COX NEWSPAPERS

CONTROL AND EMISSIONS MODELING OF VOC, AMMONIA, AND ODOR FROM PROPOSED ABT-HASKELL AIRLANCE™ COMPOST FACILITY, REDLANDS, CALIFORNIA

PREPARED FOR:

ABT-Haskell
[redacted]

PREPARED BY:

Soil/Water/Air Protection Enterprise
[redacted]

June 8, 2005

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ABBREVIATIONS

AB	Assembly Bill
ABT-Haskell	ABT-Haskell, LLC
BACT	Best Available Control Technology
°C	degrees Celsius
cfm	Cubic Feet Per Minute
CH_3CH_2COOH	Propionic Acid
$CH_3CH_2CH_2COOH$	Butyric Acid
CH_3CH_2SH	ethyl mercaptan
CH_3SH	methyl mercaptan
CH_3COOH	Acetic Acid
CIWMB	California Integrated Waste Management Board
DMS	Dimethyl Sulfide
°F	degrees Fahrenheit
GLCs	ground-level concentrations
HS^-	Sulfide
H_2S	Hydrogen Sulfide
ISCST3	Industrial Source Complex Short Term Model 3
MEK	Methyl Ethyl Ketone
$\mu g/m^3$	micrograms per cubic meter
NaOH	Sodium Hydroxide
NH_3	Ammonia
SB	Senate Bill
SCAQMD	South Coast Air Quality Management District
SO_4^{2-}	Sulfate
SWAPE	Soil/Water/Air Protection Enterprise
TGNMOC	total gaseous non-methane organic compounds
TMA	Trimethyl Amine
VFA	Volatile Fatty Acids
VOC	Volatile Organic Compound

EXECUTIVE SUMMARY

ABT-Haskell, LLC, a joint venture of American Bio Tech and The Haskell Company (ABT-Haskell) retained Soil/Water/Air Protection Enterprise (SWAPE) to prepare a report on the potential odor emissions from a proposed enclosed, in-vessel organic waste (biosolids, foodwaste, greenwaste and waste wood) composting facility located approximately one-quarter mile north of Palmetto Avenue and Alabama Street in Redlands, California (the Site). The proposed facility will be an enclosed processing center and will serve as a valuable asset to San Bernardino County in meeting the requirements of California State Assembly Bill (AB) 939. The facility will also exceed the requirements of South Coast Air Quality Management District (SCAQMD) Rule 1133.2. Moreover, the site location selected by ABT-Haskell is ideal for the proposed facility, for it is situated in close proximity to an existing wastewater treatment facility that processes sludge in the drying lagoons for open-pile composting. It is proposed and anticipated that the ABT-Haskell facility will form a cooperative agreement with the City of Redlands (operator of the wastewater treatment plant) resulting in the removal of the sludge drying lagoons and improving local air quality. Additionally, the City of Redlands has proposed that the facility utilized untapped electrical energy production that could be developed from the wastewater treatment facility's anaerobic digesters due to the production of additional methane.

Assembly Bill 939, known as the Integrated Waste Management Act, was passed in 1989 because of the statewide increases in waste stream and decreases in landfill capacity. As a result, the California Integrated Waste Management Board (CIWMB) was established. AB 939 mandates a reduction of waste being disposed in the state and mandated that jurisdictions meet diversion goals of 50% by the year 2000. The pending Senate Bill 420 has been proposed to increase the solid waste diversion rate to 75% by 2015. As of 2005, the City of Redlands is diverting only 34% of their waste according to the CIWMB. ABT-Haskell's proposed facility will assist the City of Redlands and other municipalities within San Bernardino County in meeting this goal.

SCAQMD rule 1133.2 was passed in 2003 and mandates that all compost facilities in the South Coast Air Basin: (a) conduct all active co-composting within the confines of an enclosure, (b) conduct all curing using an aeration system that operates under negative pressure for no less than 90 percent of its blower(s) operating cycle; and, (c) vent the exhaust from the enclosure and the aeration system to an emissions control system designed and operated with a control efficiency equal to or greater than 80 percent, by weight, for VOC emissions and 80 percent, by weight, for ammonia emissions.

ABT-Haskell has developed a unique and patented enclosed AirLance™ Composting Technology that uniformly keeps the compost oxidized with a mean oxygen concentration of 19%, which is far higher than any other compost process. As a result of this and other improvements in the composting process, it is likely that the SCAQMD and the CIWMB will find that American Bio Tech's AirLance™ Technology is suited to become the Best Available Control Technology (BACT) for reducing compost odor and VOC emissions.

The AirLance™ Composting Technology was utilized and constructed at two compost facilities with outstanding success in New York and Connecticut. The proposed facility in Redlands, California will process approximately 100,000 wet tons of organic waste and up to 50,000 tons of waste wood annually, and will treat the VOC, ammonia and odor emissions with the most sophisticated compost emission scrubbing system available in the United States. The proposed scrubbing system will have: (1) a heat exchanger, which will cool the exhaust air and condense or trap most of the odorants and VOCs in solution; (2) a biofilter that will oxidize much of the sulfur compounds; (3) a sulfuric acid trap that will remove any ammonia or amines that get through the condensation trap; (4) a base trap that will capture any volatile fatty acids; and (5) a sodium hypochlorite treatment train that will further oxidize any odorants, including sulfur compounds, and kill any bacteria that pass through the system.

The proposed ABT-Haskell facility in Redlands will have 16 cells with an odor control system maintaining over a 60 second contact time. Two similar facilities have been constructed in New York (with 4.5 compost cells) and Connecticut (with 20 compost cells). The New York and Connecticut facilities had simple acid and base wet scrubbing systems with only 6 to 7 second contact times, which were sufficient to control odor emissions. The proposed ABT-Haskell facility in Redlands (with 16 compost cells) will a employ a wet scrubbing system with three additional treatment trains (heat exchanger/condensation trap, biofilter, and sodium hypochlorite misting system), in addition to the acid and base wet scrubbing treatment. The contact time at the Redlands Facility will be approximately 9 to 10 times greater than the previously constructed facilities that successfully controlled odor. The proposed Redlands facility, with its increased contact time and three additional odor control processes, will ensure that the potential to produce odors which may impact the community is *de minimus*.

To estimate potential ground-level concentrations of odorants from the facility, SWAPE compiled "worst-case" scenario compost emission data from studies performed by the SCAQMD on the San Joaquin Composting, Incorporated (Lost Hills, California) and EKO Systems (Corona, California) open-pile facilities. The term "worst-case" scenario is used because open-pile composting has been shown to be a mostly anaerobic (lacking oxygen) process that is not directly applicable to the highly aerobic AirLance™ process. With this in mind, emission factors were derived for ammonia, sulfur compounds, amine compounds, and VOCs above those outlined in SCAQMD Rule 1133.2. SWAPE estimated the potential ground-level concentrations of each of the odorants of concern (sulfur compounds, ammonia, amines, and VOCs) using the Industrial Source Complex Short Term Model 3 (ISCST3) for a variety of periods (1-hour, 12-hour, and annual average) as well as for a variety of control conditions (80% control of emissions, 95% control of emissions, 99% control of emissions, and 99.9% control of emissions). The modeling demonstrated that when the system is operational the proposed ABT-Haskell composting facility will have a *de mininus* impact upon the Redlands Community with regard to odor and volatile organic compounds emissions. In conclusion, the County of San Bernardino should embrace the ABT-Haskell project, for it will facilitate a process for local municipalities to meet the requirements for waste diversion from landfills under AB 939 and the project will have a *de minimus* impact upon the community. Moreover, the County of San Bernardino can be a leader in California for organic waste recycling by supporting such a sophisticated green industrial recycling technology.

1 INTRODUCTION

Soil/Water/Air Protection Enterprise (SWAPE) has prepared this report to assist in evaluation of odor emissions from the proposed ABT-Haskell organic waste composting facility located approximately one-quarter mile north of Palmetto Avenue and Alabama Street in Redlands, California (the Site).

This report presents the following information:

1. A literature review of biosolids compost odorants;
2. Description of the AirLance™ Technology that maintains an aerobic environment ;
3. Description of the proposed air scrubber system that eliminates emissions/odors;
4. Compost facility emissions inventory;
5. Local meteorological data; and
6. Modeling of potential offsite emission/odors from the proposed facility

1.1 COMPOSTING PROCESS

SCAQMD defines composting as an aerobic (oxygen dependent) degradation process by which organic wastes decompose under controlled conditions[1]. Composting typically involves the mixing of digested sewage sludge and other organic wastes with a bulking agent at an approximate 50-50 ratio. The final compost product is stable, free of pathogens, and can be used as a soil amendment and fertilizer. The bacterial breakdown of substrates also produces by-product organic and inorganic gases[2]. Emissions monitored in studies by SCAQMD include ammonia, amines, total sulfur compounds, methane, and total gaseous non-methane organic compounds (TGNMOC).

[1] SCAQMD. 1995. *Final Report: Emission Rate Characterization of Open Windrow Sludge Composting Operations*. South Coast Air Quality Management District. October, 1995. page 2

[2] SCAQMD. 1995. *Final Report: Emission Rate Characterization of Open Windrow Sludge Composting Operations*. South Coast Air Quality Management District. October, 1995 page 2

1.2 SCAQMD RULE 1133.2 -- EMISSION REDUCTIONS FROM CO-COMPOSTING OPERATIONS

Under SCAQMD Rule 1133.2 compositing facilities are to reduce volatile organic compounds (VOC) and ammonia (NH_3) emissions from co-composting operations[3]. A copy of Rule 1133.2 is attached as Appendix A. In addition to enclosing facilities, operators are required to have facilities in which:

(A)

(i) The inward face velocity of air through each opening in which air can enter the enclosure shall be a minimum of 100 feet per minute, unless the opening is equipped with a closure device that seals the opening in the event that the airflow direction changes.

(ii) The area of all openings in the enclosure through which air can enter the enclosure shall not exceed 2% of the surface area of the enclosure's four walls, floor, and ceiling.

(iii) The enclosure may be opened for brief time periods, not to exceed a total of 30 minutes per day for purposes of access or maintenance. These time periods do not need to be included in the face velocity determination or as an opening for the two percent criteria.

(iv) No measurable increase over background levels of ammonia or hydrocarbons outside the enclosure shall occur at any enclosure opening including any opening that occurs briefly for access or maintenance. A portable ammonia or hydrocarbon analyzer shall be used for these measurements. The portable ammonia analyzer shall be operated per manufacturer's instructions and calibrated with certified zero and 10 parts per million ammonia standards. The portable hydrocarbon analyzer shall be a flame ionization detector operated per manufacturer's instructions and calibrated with certified zero and 10 parts per million methane standards.

(B) Conduct all curing using an aeration system that operates under negative pressure for no less than 90 percent of its blower(s) operating cycle; and,

(C) Vent the exhaust from the enclosure and the aeration system to an emissions control system designed and operated with a control efficiency equal to or greater than 80 percent, by weight, for VOC emissions and 80 percent, by weight, for ammonia emissions.[4]

The practical result of the Rule is that all emissions from new composting facilities must be reduced by 80 percent (Paragraph (d)(2)). Paragraph (d)(3) of Rule 1133.2 allows existing composting facilities to reduce emissions to 70 percent.

Paragraph (d)(4) details baseline emission factors that may be used to determine the amount of VOC and NH_3 generated per ton of throughput (1.78 and 2.93 lbs per ton, respectively). These baseline emission factors may be used in lieu of specific emission factors when submitting a compliance plan for the proposed operations of new composting facilities. The emission factors represent non-controlled operations.

Conservative emission factors were derived from SCAQMD studies of open-pile composting systems for this assessment. This conservative approach will over-estimate the potential for emissions from the facility, providing a higher level of protection for the community by ensuring appropriate control measures are in place.

1.3 LANDFILL CAPACITY AND SOLID WASTE DIVERSION

Because of state-wide increases in solid waste streams and decreases in landfill capacity, the California legislature enacted Assembly Bill 939 (AB 939) and Senate Bill 1322 (SB 1322), known as the Integrated Waste Management Act, in 1989. The California Integrated Waste Management Board (CIWMB) was created as a result of this legislation and its authority and responsibilities were signed into law as the Integrated Waste Management Act of 1989.[5]

The Integrated Waste Management Act established a new approach to managing California's solid waste stream, the centerpiece of which was a mandated 25 percent diversion of each city's and county's waste from disposal by 1995, and 50 percent

[3] SCAQMD Rule 1133.2 - Reductions From Co-Composting Operations *(Adopted January 10, 2003)*

[4] SCAQMD Rule 1133.2 - Reductions From Co-Composting Operations *(Adopted January 10, 2003)*

[5] CALEPA. 2003. The History of the California Environmental Protection Agency, The Integrated Waste Management Board. http://www.calepa.ca.gov/About/History01/ciwmb.htm.

diversion in 2000, along with a process to ensure environmentally safe disposal of waste that could not be diverted.[6]

The Integrated Waste Management Act, along with Title 14 and Chapter 15 of California's environmental regulations, also provided the foundation to put the state on course to comply with federal standards (Title 40, Code of Federal Regulations, Part 258, Subtitle D) for managing solid waste, including the design, construction and operation of landfills. In 1993, California became one of the first states to receive federal approval to assume authority over its solid waste activities, having actually exceeded the federal standards through the adoption of more stringent State regulations. Since then, the environmental performance of waste handling facilities in California have steadily improved and today rank the State as a world leader.[7]

The statewide solid waste diversion rate reached approximately 37 percent in 1999, continuing an upward trend that started with a rate of about 10 percent in 1989. Recent legislation, namely in Senate Bill (SB) 420, has been proposed to increase the solid waste diversion rate to 75% diversion by 2015.[8] ABT-Haskell's proposed facility will assist San Bernardino County in meeting this goal by recycling organic and carbonous (wood) wastes that are currently being landfilled.

[6] CALEPA. 2003. The History of the California Environmental Protection Agency, The Integrated Waste Management Board. http://www.calepa.ca.gov/About/History01/ciwmb.htm.

[7] CALEPA. 2003. The History of the California Environmental Protection Agency, The Integrated Waste Management Board. http://www.calepa.ca.gov/About/History01/ciwmb.htm.

[8] Amended Senate Bill 420. March 29, 2005. http://info.sen.ca.gov/pub/bill/sen/sb_0401-0450/sb_420_bill_20050329_amended_sen.html

2 ODORANT LITERATURE REVIEW

2.1 ODORANT OVERVIEW

Odorous emissions from biosolids composting operations are believed to result primarily from sulfur and nitrogen compound emissions. Furthermore, ketones and volatile fatty acids have also been noted as odorant emissions from biosolids (Mosier et al., 1977).

Because each odorant has unique physical and chemical properties and odor characteristics or type (e.g. rotten vegetable, fishy), it is essential to correctly identify the odorants type in order to solve the problem and come up with an engineering solution. Moreover, it is important to identify individual chemicals responsible for the odor and conduct a health risk assessment in order to explain the relative risk to the community affected by the odor.

Odor has traditionally been evaluated using dilution-to-threshold olfactometry and via chemical analyses of common odorants. While dilution-to-threshold olfactometry is useful in determining the relative intensity of an odor, it does not address the relative offensiveness or character of the odor.

Odor emissions from biosolids composting are affected by (1) biosolids composition, (2) environmental variables, and (3) management practices. Different biosolids can have different chemical constituents, microbial communities, decomposition rates, odorous compounds, and odorant volatilization rates. Environmental variables that affect odor emissions include temperature, moisture, time, wind, redox potential, microorganisms, pH and structure (Miller, 1993).

2.2 ODORANT EMISSIONS FROM BIOSOLIDS

2.2.1 SULFUR EMISSIONS FROM BIOSOLIDS

Biosolids typically contain between 0.7 to 2.1% total elemental sulfur (Sommers et al., 1977), and some fraction of this sulfur volatilizes producing odor. Banwart and Bremner (1975) found that dimethyl disulfide accounted for 55-98% of total sulfur evolved from biosolids application to soil in aerobic conditions, which in many ways is similar to composting (Figure 2.1). Dimethyl disulfide is produced by many bacteria found in wastewater (Tornita et al., 1987) and fungi (Sunesson et al., 1995; Borjesson et al., 1993) and possesses a rotten cabbage odor with a low human detection limit of 0.1 micrograms per cubic meter ($\mu g/m^3$) (Ruth, 1986).

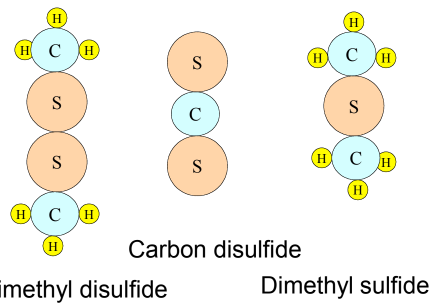


Figure 2.1: Sulfur Compounds

Dimethyl sulfide and carbon disulfide (Figure 2.1) are the other two most abundant sulfur emissions from biosolids application and composting in aerobic conditions (Banwart and Bremner, 1976). Dimethyl sulfide and carbon also possess a rotten cabbage smell, with human detection limits of 2.5 μg/m3 and 24.3 μg/m3 respectively (Ruth, 1986).

Sommers et al. (1977) characterized the forms of sulfur in 10 biosolids from different Indiana cities and found that approximately 65% of the sulfur was in the organic form. Organic-sulfur in biosolids can produce dimethyl disulfide, dimethyl sulfide and carbon disulfide (Banwart and Bremner, 1975). Sommers et al. (1977) found that approximately 35% total sulfur in biosolids was inorganic (with sulfide (HS-) accounting for 8.5% of total sulfur). Bacteria and fungi typically promote the methylation of HS- producing thiols and various methyl sulfides (Miller, 1993). The oxidation of methyl sulfides can produce dimethyl disulfide (Wilber et al., 1991).

Carbon disulfide has been documented to form in both aerobic and anaerobic environments via microbial decomposition of sulfide containing amino acids found in protein. Banwart and Bremner (1975a) reported that carbon disulfide emissions resulted from decomposition of cysteine, cystine, homocystine, lanthionine, and Djenkolic acid.

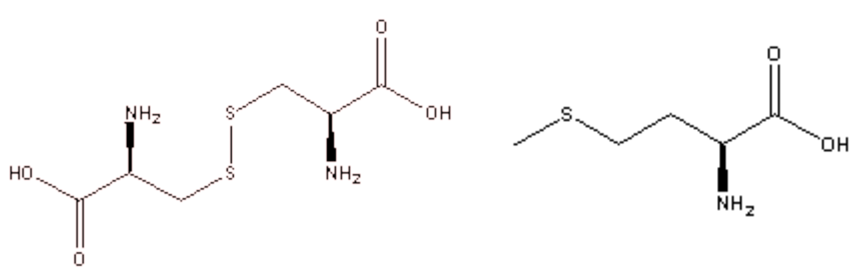
Hydrogen sulfide (H_2S) has not been found to volatilize following biosolids application to soil in aerobic conditions (Banwart and Bremner, 1976), and is not found in aerobic biosolids composting. Biosolids often have a pH around 8.5, and at this pH H2S (pKa=7.04) deprotonates to sulfide (HS-), a non-volatile ionic molecule. Furthermore

H2S is a polar molecule with a structure similar to water, and is held in solution via hydrogen bonding. In addition, H2S is readily oxidized in aerobic conditions (Paul and Clark, 1996). Bacteria and fungi can also remove HS- by promoting methylation, producing thiols and various methyl sulfides (Miller, 1993).

Finally, methyl mercaptan (CH_3SH) and ethyl mercaptan (CH_3CH_2SH) are not detected resulting from biosolids in aerobic conditions (Banwart and Bremner, 1976). Although these compounds are present in the ambient air near wastewater facilities, these compounds are highly reactive and are easily catalyzed forming disulfides (Huang, 1994).

Dimethyl sulfide (DMS) has been documented to form in both aerobic and anaerobic environments via microbial decomposition of sulfur containing amino acids found in protein. Banwart and Bremner (1975) reported that dimethyl sulfide emissions resulted from methionine and homocystine. The degradation of sulfur containing amino acids, specifically cystine and methionine can produce hydrogen sulfide and DMS under anaerobic conditions (Oho et al, 2000, Persson 1992).

Amino acids are the monomers of protein and both cysteine and methionine have been shown to be present in extracted from activated sludges and anaerobically digested sludges (Higgins and Novak, 1997). This mechanism would likely entail the sequential step of the breakdown of protein for form peptides and degradation of peptides for form these free amino acids which would then be broken down to from volatile sulfur compounds.



Cystine Methionine

Figure 2.2: Amino Acids

2.2.2 NITROGEN EMISSIONS

Ammonia and trimethyl amine comprise most of the odorous nitrogen emissions from biosolids composting (Figure 2.2). Ammonia produces a pungent medicinal odor with a human detection limit of 26 μg/m^3 (Ruth, 1986), while TMA produces a fishy odor with a human detection limit 100 times lower at only 0.8 μg/m^3 (Ruth, 1986).

The major biological forms of nitrogen include amino acids and nucleic acids (Paul and Clark, 1996). These materials are present in wastewater and mineralize, resulting in NH_4^+ formation (Mitsch and Gosselink, 1993). Anaerobically digested biosolids typically contain between 3 to 6% nitrogen, and 40 to 75% of nitrogen is organic-nitrogen, while the balance is NH_4^+-N (Kardos et al., 1977). Typically, the NH_4^+ ion in biosolids quickly deprotonates resulting in volatile NH_3. Ammonia emissions are reported to be highest during the first several days after biosolids application and then significantly drop off (Harmel et al., 1997). Furthermore, Beauchamp et al. (1978) found that temperature was the most important variable explaining NH_3 volatilization during the first few days after application.

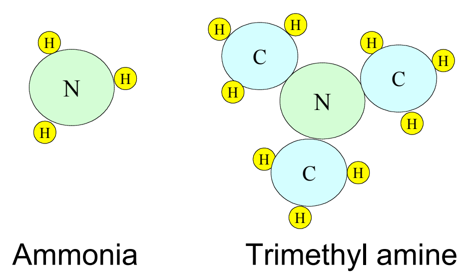


Figure 2.3: Nitrogen Compounds

Hutchenson et al. (1982) measured NH_3 and amine emissions above a cattle feedlot, finding that the NH3-N flux was equal to 99% of the total nitrogen-flux, while the amine flux was equal to approximately 1% of total nitrogen-flux. Of the amines, TMA was always present in highest concentrations and exceeded the sum of other atmospheric amines by sevenfold. Trisubstituted amines (such as TMA) are apparently less readily attacked than are monoamines by the microorganisms active in fecal protein catabolism (Thimann, 1963).

Schade and Crutzen (1995) investigated N emissions from chicken, cow, horse, and swine feces and found that the NH3-N flux was 99.3% of the N-flux, while amines were approximately 0.7% of the N-flux. The amine emissions consisted almost entirely of methyl amines and correlated with NH3 emissions. Of the amines, TMA exceeded the sum of other atmospheric amines by three times.

2.2.3 KETONE EMISSIONS

Humans are not particularly sensitive to acetone and methyl ethyl ketone (MEK), with human detection limits of 1100 $\mu g/m^3$ (Ruth, 1986) and 750 $\mu g/m^3$, respectively (Ruth, 1986). While the sweet solvent-like odors of ketones may not be perceived as unpleasant, mixed with other odorants they contribute to a generally unpleasant odor.

Ketones can be formed via anaerobic decomposition of cellulose, starch, hemicellulose, and pectins (Mosier et al., 1977). Clostridium sp. bacteria have been identified as acetone producers (Holdemand and Moore, 1973; El Ammouri, 1987; Martin, 1983) and are obligate anaerobes (Killham, 1994). Furthermore, Clostridium sp. has been identified in wastewater and biosolids (Gold et al., 1992; Garcia and Bacares, 1997; Edwards et al., 1998). Van Durme et al. (1992) identified a number of ketones including acetone and methyl ethyl ketone (MEK) as odorant emissions from composting of biosolids (Figure 2.4)

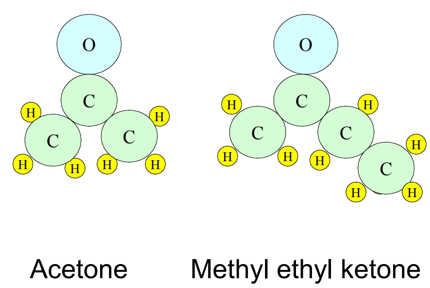


Figure 2.4: Ketones

2.2.4 VOLATILE FATTY ACID EMISSIONS

During wastewater treatment and the anaerobic digestion process, starch, cellulose and hemicellulose are broken down by acid forming bacteria into short chain volatile fatty acids (VFAs) (Figure 2.5). Methanogens, or methane producing bacteria, then convert VFAs into methane (Paul and Clark, 1996).

Thermophillically digested biosolids (50° to 55°C) usually produce more VFA emissions than mesophillically digested biosolids (30° to 35°C), resulting from both higher temperatures and shorter anaerobic digester detention times (Cecil et al., 1992). Volatile fatty acids seldom contribute to the odor from aerobic biosolids at room temperature, for the boiling points for acetic, propionic, and butyric acids are 118, 141, and 164°C, respectively. However, researchers have detected volatile fatty acids during heating of biosolids. For instance, acetic acid was the major VFA produced when diluted biosolids were heated to 121°C (Badawi, 1992). Acetic acid was found in high concentration when sewage sludge was pyrolized at 250°C (Conesa et al., 1998).

According to Mackie (1994), the greater the chain length and the more branching that exists in low molecular weight VFAs, the greater the offensiveness of the odor associated with these acids. For instance, the human detection limits for acetic (CH_3COOH), propionic (CH_3CH_2COOH), and butyric ($CH_3CH_2CH_2COOH$) acids are 2500, 84, 1 μg/m^3 respectively (Ruth, 1986).

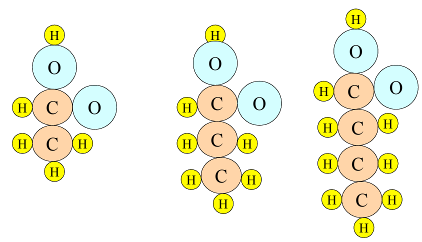


Figure 2.4: Volatile Fatty Acids

2.2.5 ODORANT DETECTION LIMITS

For a person to smell something, air containing odorant molecules must reach a tiny cluster of specialized nerve cells called olfactory neurons. Each nasal cavity has 5 million olfactory neurons, which can perceive 4000 different odors. However, the average individual can only name a handful of odors. This limitation is a result of an individual's inability to name a substance, rather than failure to detect the difference between odors (Ruth, 1986).

A classical definition of odor threshold is the minimum concentration of an odorant which produces a noticeable change in the odor of the system (Ruth, 1986). Odorous samples are presented to panelists by starting with a blank and increasing odorant concentration until odor is perceived. The lowest reported published human detection limits for various odorous compounds are listed in Table 2.1.

It must be noted that data in Table 2.1 are for single odorants when no other odorants are in the air. When two different odorants are introduced into a system, they can act in a synergistic, additive, independent, or counteractive way. To date, mixtures of chemicals have received very little study (Ruth, 1986) (Appendix B).

Table 2.1: Published human detection limits for biosolids compost odorants

Compound	Odor Character	Low Odor Detection Limit (ug/m^3)	High Odor Detection Limit (ug/m^3)	Source
Dimethyl Disulfide	Rotten Cabbage	0.1	246	Ruth, 1986
Hydrogen Sulfide	Rotten Eggs	0.7	14	Ruth, 1986
Dimethyl Sulfide	Rotten Cabbage	2.5	50	Ruth, 1986
Carbon Disulfide	Rotten Cabbage	24	23100	Ruth, 1986
Ammonia	Medicinal	26.6	39600	Ruth, 1986
Trimethyl Amine	Fishy	0.8	0.8	Ruth, 1986
Methyl Ethyl Ketone	Sweet	750	737	Ruth, 1986
Acetone	Sweet	47466	1613860	Ruth, 1986
Acetic Acid	Vinegar	2500	250000	Ruth, 1986
Propionic Acid	Vinegar	84	60000	Ruth, 1986
Butyric Acid	Vinegar	1	900	Ruth, 1986

3 PROPOSED DEVELOPMENT USING AIRLANCE™ TECHNOLOGY

3.1 ABT-HASKELL DEVELOPMENT

ABT-Haskell is proposing to develop a completely enclosed organic waste composting facility in Redlands, California, utilizing AirLance™ Technology that will process approximately 100,000 wet tons of organic waste annually. Additionlly, the proposed facility will process between 25,000 and 50,000 tons of waste wood (green-waste) annually. The site selected by ABT-Haskell is ideal for the proposed facility, for it is in close proximity to a wastewater treatment facility with sludge drying lagoons, and is bordered by two solid waste landfills. It is anticipated that this proposed facility will result in removal of the sludge drying lagoons, thus improving local air quality. The facility will process compost in less time, produce fewer emissions, and subsequently fewer odors (detailed below).

The City of Redlands wastewater treatment facility is located at the north end of Nevada Street, on approximately 50 acres adjacent to the Santa Ana River (northwest of the proposed facility). The City of Redlands facility has been modified to provide secondary Wastewater treatment. Wastewater solids are settled in large tanks and then removed, dried and then composted at OneStop Landscape, an open pile composting facility located in Redlands, CA. The liquid portion is combined with "safe to humans" bacteria and processed further as the bacteria consume over 95% of the water born pollutants. The processed water is then percolated back into the groundwater basin. The City of Redlands facility has the ability to process 9.5 million gallons of wastewater per day, and is currently processing about 6 million gallons per day.

The ABT-Haskell plant will be equipped with an emission scrubbing system capable of treating VOC, ammonia, and odor emissions in excess of the requirements for emission controls as outlined in AB 1133.2. The facility will achieve emission controls in excess of 99% (detailed in section 4.0). The proposed scrubbing system will have: (1) a heat exchanger which will cool the exhaust air and condense or trap most of the odorants and VOCs in solution; (2) a biofilter that will oxidize much of the sulfur compounds; (3) a sulfuric acid trap that will remove any ammonia or amines that get through the condensation trap; (4) a base trap that will capture any volatile fatty acids; and (5) a sodium hypochlorite treatment train that will further oxidize any odorants including sulfur compounds and kill any bacteria that get through the system.

3.2 AIRLANCE TECHNOLOGY

The AirLance™ Process allows composting to be maintained at a maximum biological rate with minimal material handling and low energy consumption. Composting inside the cubical cells remains above 55 degrees Celsius for the full composting period, assuring that the composting process is rapid and cost effective. The compost remains in the system for 14 to 28 days, which is determined by the waste processed, and it leaves as a finished product.

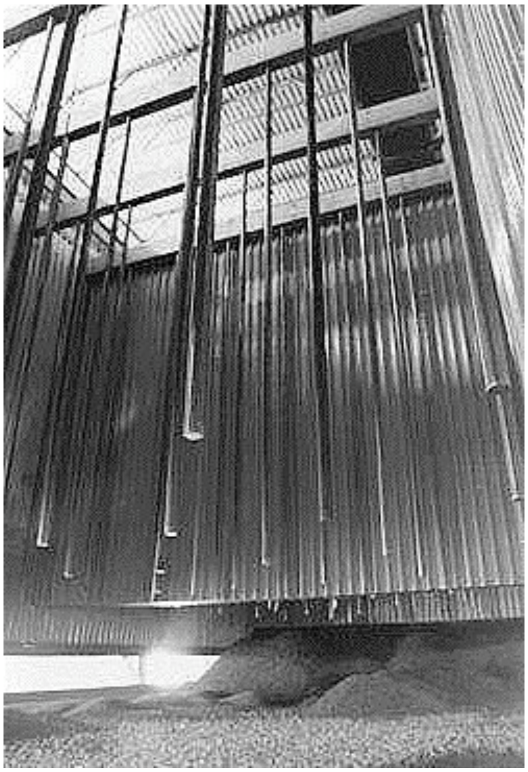



Figure 3.1 & 3.2: The figure on the left shows the Air Lance technology from the bottom of each cell. The figure on the right demonstrates how the air flow through the compost keeps the cells oxygenated

According to the designers, advantages of the AirLance™ Process over open-pile systems include:

1. Reduction in Material Handling

In the AirLance™ System the compost biomass mix is only handled twice during the composting process, loading and unloading the cell. The AirLance™ process does not require the compost to be re-piled and moved numerous times for curing, sorting, and screening.

2. Aerobic BioMass

The AirLance™ Process maintains aerobic conditions by uniformly aerating evenly throughout the biomass to maximize the rate of organic waste stabilization. What is often not realized is that within 20 minutes after making a conventional compost pile, the main mass is depleted of oxygen and the microbes are dying. The center only stays warm because it is well insulated. Daily mixing of windrow composting piles releases anaerobic odors, re-aerates, releases heat, and restarts the process. This is why windrow composting takes considerably longer to complete the process. Static pile composting doesn't significantly change this problem. Attempting to aerate a large pile from the bottom is not very effective. Fluid (air) will always find the path of least resistance and short circuit.

3. Process Time

In the AirLance™ Process all compost is contained inside the system for the full 14 to 28-day composting period. The compost is maintained at 55 to 80 degrees centigrade over the full period, assuring that the compost is a finished stabile product when it leaves the system. Many composting systems only contain the compost in their systems for a few days, and then they pile the compost outside to finish the process. Only because containing the compost for a full 14 to 28 days would make their systems far too expensive to build and operate.

4. Capacity Rating

The AirLance™ Process allows all compost to be loaded into the system as a fine and uniform product. Large chunks of waste to build pore space for aeration are not required. Large pieces only have to be removed later adding another step in the process. This also means that 100% of the product leaving the AirLance™ composting cell is finished, ready for use, and it does not require further screening or recycling.

When finished compost from a windrow composting operation needs to be re-screened to remove foreign material after the process; it also means you have wasted valuable space in the composting operation with non-compost product. A compost process should be capacity rated by the amount of compost it produces, not by what was loaded into the system, and later removed.

More important this means the AirLance™ process can process 2 to 4 times more compost in an equivalent size system. This unique ability of the AirLance™ System to compost a fine material becomes a significant economic advantage in the big picture.

5. Daily Mixing

In the AirLance™ Process all compost is remixed daily. By using gravity to accomplish the mixing action, it requires only 5 to 10% of the energy of other processes to mix. Compost is mixed daily without fear of extensive heat loss.

6. Material Handling Efficiency

The high material handling efficiency of the AirLance™ Process design frequently uses less than 10% of the time and energy for loading / unloading of other composting processes.

7. Aeration Efficiency

The high efficiency of the AirLance™ Aeration Process design greatly reduces energy cost for aeration, ventilation, and odor control compared to other composting processes.

8. Odor Control

The high efficiency of the AirLance™ Aeration Process design simplifies odor control. It reduces the volume of odorous air and allows for a much smaller and more effective odor control system to be built.

3.3 OXYGEN CONTENT AND ODOR EMISSIONS

Maintaining an oxygen content above 15% greatly reduces odor during composting. Ambient air contains 21% oxygen. When the oxygen content in a compost pile falls below 15% reduced sulfides form via reduction of sulfur, and volatile fatty acids, ketones and aldehydes form via incomplete oxidations of cellulose and other carbon substrates. Unfortunately, most composting processes have very low oxygen concentrations.

Dr. Mike Robe (Robe, 2005) conducted experiments measuring the oxygen content throughout an windrow composting facility and found that the oxygen content dropped to below 5% within one hour of composting (Figures 3.3 and 3.4). Hence one can assume that the center of most windrow composting piles are anaerobic forming odorous reduced sulfides, ketones, aldehydes.

The AirLance™ Aeration Process eliminates this anaerobic process and effectively eliminates the formation of the most odorous compounds found in emissions from composting. Instead of reduced sulfides forming via anaerobic conditions, sulfate (SO_4^2) forms that is a non-volatile ion with no odor. Moreover, with sufficient oxygen, cellulose can break down all the way to CO_2 and H_2O rather than forming intermediate ketones, aldehydes and fatty acids.

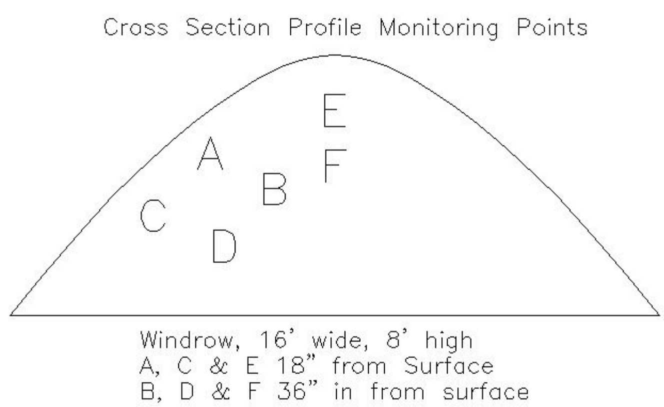


Figure 3.3: Cross Section Of Typical Windrow Composting (Robe, 2005)

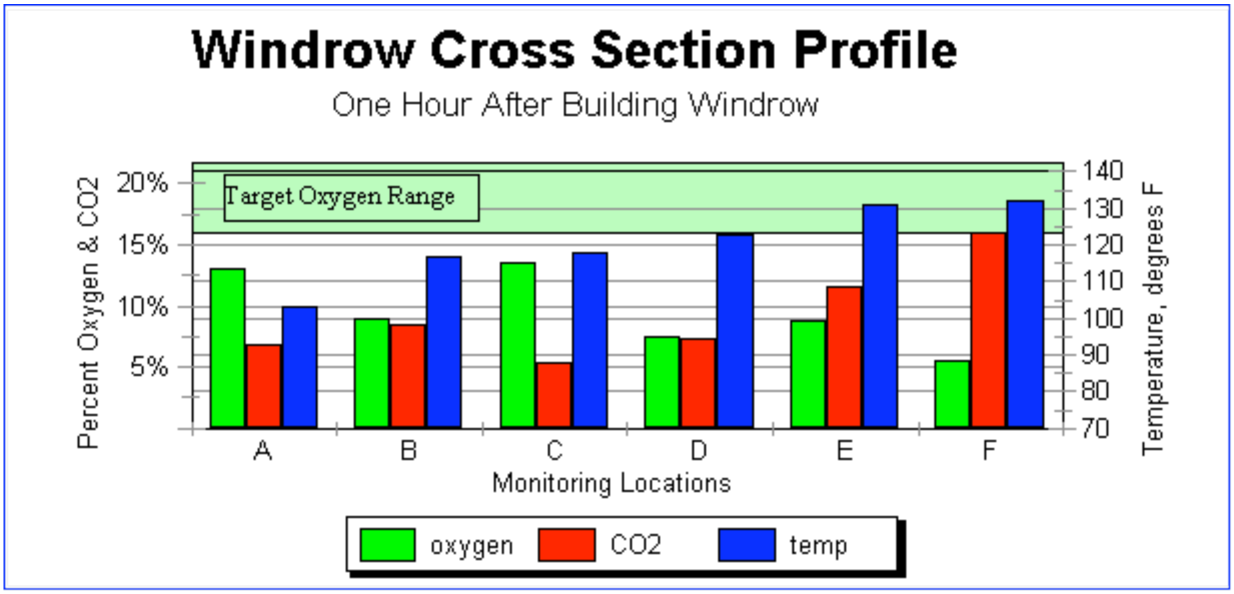


Figure 3.4: Oxygenc and Carbon In Relation To Cross Section In Figure 3.3 (Robe, 2005)

4 AIR SCRUBBER SYSTEM THAT ELIMINATES EMISSIONS/ODORS

ABT-Haskell has proposed to construct the largest and most advanced odor treatment system ever designed in the compost industry. The proposed air scrubbing system will have several stages and more than sixty (60) seconds of contact time. The treatment processes will include: (1) a heat exchanger and condensation trap; (2) a biofilter; (3) sulfuric acid wet scrubber; (4) a sodium hydroxide base wet scrubber; and (5) a sodium hypochlorite oxidizing wet scrubber. Each of these treatment processes are described below.

The proposed ABT-Haskell facility in Redlands will have 16 cells with an odor control system maintaining over a 60 second contact time. Two similar facilities have been constructed in New York (with 4.5 compost cells) and Connecticut (with 20 compost cells). The New York and Connecticut facilities had simple acid and base wet scrubbing systems with only 6 to 7 second contact times, which were sufficient to control odor emissions. The proposed ABT-Haskell facility in Redlands (with 16 compost cells) will a employ a wet scrubbing system with three additional treatment trains (heat exchanger/condensation trap, biofilter, and sodium hypochlorite misting system), in addition to the acid and base wet scrubbing treatment. The contact time at the Redlands Facility will be approximately 9 to 10 times greater than the previously constructed facilities that successfully controlled odor. The proposed Redlands facility, with its increased contact time and three additional odor control processes, will ensure that the potential to produce odors which may impact the community is *de minimus*.

4.1 HEAT EXCHANGER AND CONDENSATION TRAP

The heat exchanger will reduce the temperature of the influent to the scrubbing system from approximately 130 degrees Fahrenheit (°F) to 90 °F. Dew point is the temperature at which condensations forms. This component of the treatment system is designed to remove 99.9% of the ammonia. When air comes in contact with a surface that is at or below its dew point temperature, condensation will form on that surface. With a 100 percent relative humidity at 90 °F, all gasses should condense to liquid and fall out in the condensation trap.

4.2 BIOFILTER

A biofilter will be installed in line to oxidize a wide variety of odorants including any nitrogen, sulfur, ketone, and aldehyde compounds that get through the system. The biofiter polypropylene labyrnith with filter media allowing for bacterial populations to accumulate.

4.3 SULFURIC ACID

Sulfuric acid wet scrubbing will be used to trap any amines or ammonia that get through the heat exchanger and condensation trap, although the ammonia and amine concentrations should be at non-detect. Sulfuric acid reacts with ammonia gas (NH_3) by donating a proton, forcing ammonia gas to become ammonium (NH_4^+) that is then in solution as an ion. The sulfuric acid will be fine misted into the system.

4.4 SODIUM HYDROXIDE

Sodium hydroxide (NaOH) traps volatile fatty acids. The sodium hydroxide will be fine misted into the system.

4.5 SODIUM HYPOCHLORITE

Sodium hypochlorite or bleach will be used as an oxidizing agent for sulfur compounds, and any other odorants or bacteria that come into contact with this oxidizing agent. The sodium hyperchlorite will be fine misted into the system.

5 EMISSIONS INVENTORY

Potential emissions from the facility were derived from source test reports of open-pile composting systems completed by the SCAQMD. SCAQMD defines composting as an aerobic (oxygen dependent) degradation process by which organic wastes decompose under controlled conditions.[9] The final product is stable, free of pathogens, and can be used as a soil amendment and fertilizer. The bacterial breakdown of substrates also produces by-product organic and inorganic gases.[10] Emissions monitored in studies by SCAQMD include ammonia, amines, total sulfur compounds, methane, and total gaseous non-methane organic compounds (TGNMOC).

Methane is produced during the anaerobic decomposition of organic material.[11] According to SCAQMD, the amount of methane generated is a function of the fraction of the total waste that is available for anaerobic bacteria, temperature, and moisture.[12] For windrow operations, methane production is highest in the first 21 days of composting. Since the AirLance™ method involves aerobic composting, methane is not produced in the system. Therefore, methane will be excluded from the emission inventory for the proposed plant.

For the SCAQMD studies, sampling was performed in order to inventory emissions from sludge composting operations in the South Coast Air District in order to evaluate the impact of the operations for possible inclusion to the Air Quality Management Plan (AQMP).[13,14] The facilities had been volunteered for sampling by the owners. Emissions were collected from the piles at various points in the composting cycle. According to the reports, the days for sampling were chosen to represent the beginning

[9] SCAQMD. 1995. *Final Report: Emission Rate Characterization of Open Windrow Sludge Composting Operations*. South Coast Air Quality Management District. October, 1995. page 2

[10] SCAQMD. 1995. *Final Report: Emission Rate Characterization of Open Windrow Sludge Composting Operations*. South Coast Air Quality Management District. October, 1995 page 2

[11] SCAQMD. 1995. *Final Report: Emission Rate Characterization of Open Windrow Sludge Composting Operations*. South Coast Air Quality Management District. October, 1995. page 12

[12] SCAQMD. 1995. *Final Report: Emission Rate Characterization of Open Windrow Sludge Composting Operations*. South Coast Air Quality Management District. October, 1995. page 12

[13] SCAQMD. 1996. *Source Test Report 96-0007/96-0008/96-0009 Conducted at San Joaquin Composting Inc, Holloway Road, Lost Hills, California, Characterization of Ammonia, Total Amine, Organic Sulfur Compound, and Total Non-Methane Organic Compound (TGNMOC) Emissions from Composting Operations*. South Coast Air Quality Management District. November 16, 1996.

[14] SCAQMD. 1996. *Source Test Report 95-0032/96-0003 Conducted at EKO Systems 8100-100 Chino-Corona Road, Corona, California, 91720, Characterization of Ammonia, Total Amine, Organic Sulfur Compound, and Total Non-Methane Organic Compound (TGNMOC) Emissions from Composting Operations*. South Coast Air Quality Management District. May 16, 1996.

of the composting cycle, the peak temperature day, and the ending day of the composting cycle. The reported emissions were for windrows at the sites since sampling for curing piles emissions was not performed. Piles at the site were turned one to three times per week and samples were collected after turning had been completed. The turning process can release large quantities of emissions and sampling was performed after turning was completed.

The first study of the San Joaquin Composting, Incorporated[15] facility located on Holloway Road, in Lost Hills, California, measured the emission profile of the operation over the composting cycle. The facility composted piles of dewatered sewage sludge and green waste. Emissions were collected from the piles on days 3, 45, and 57 of the composting cycle. The estimated facility wide emissions did not include curing pile emissions and were calculated using the average of the three windrow ages[16].

Table 5.1: San Joaquin Composting, Incorporated Facility Average Emissions for 3, 45, and 57 Day Piles:

Chemical	Emissions per ton of Compost Mix
Ammonia	2.81 lbs/ton mix
Amines	0.19 lbs/ton mix
Total Sulfur Compounds	0.22 lbs/ton mix
TGNMOC	3.12 lbs/ton mix

The second study performed by SCAQMD was of the EKO Systems[17] facility located at 8100-100 Chino-Corona Road, Corona, California, measured the emission profile of the operation over the composting cycle. The facility composted piles of dewatered sewage sludge and manure. Emissions were collected from the piles on days 2, 20, and 50 of the composting cycle. According to the report, the days for sampling were chosen as the beginning of the composting cycle, the peak temperature day, and the ending day of

[15] SCAQMD. 1996. *Source Test Report 96-0007/96-0008/96-0009 Conducted at San Joaquin Composting Inc, Holloway Road, Lost Hills, California, Characterization of Ammonia, Total Amine, Organic Sulfur Compound, and Total Non-Methane Organic Compound (TGNMOC) Emissions from Composting Operations*. South Coast Air Quality Management District. November 16, 1996.

[16] ibid

[17] SCAQMD. 1996. *Source Test Report 95-0032/96-0003 Conducted at EKO Systems 8100-100 Chino-Corona Road, Corona, California, 91720, Characterization of Ammonia, Total Amine, Organic Sulfur Compound, and Total Non-Methane Organic Compound (TGNMOC) Emissions from Composting Operations*. South Coast Air Quality Management District. May 16, 1996.

the composting cycle. The reported emissions were for windrows at the site since sampling for curing piles emissions was not performed. Piles at the site were turned one to three times per week and samples were collected after turning had been completed. The estimated facility wide emissions did not include curing pile emissions and were calculated using the average of the three windrow ages[18].

Table 5.2: EKO Systems Average Emissions for 2-day, 20-day, and & 50-Day Piles:

Chemical	Emissions per ton of Compost Mix
Ammonia	3.28 lbs/ton mix
Amines	<0.0003 lbs/ton mix
Total Sulfur Compounds	0.015 lbs/ton mix
TGNMOC	1.70 lbs/ton mix

An average value from the two studies was estimated and used as the source term for the dispersion model. The average was used rather than the default emission factors listed in SCAQMD Rule 1133.2 since

1. The San Joaquin facility composted 50% biosolids and 50% greenwaste;
2. The EKO facility composted manure and biosolids; and
3. The feedstock of the proposed ABT-Haskell facility will be similar to a mixture of the San Joaquin and EKO facilities.

The average values are:

Table 5.3: Average Emissions for San Joaquin and EKO Studies:

Chemical	Emissions per ton of Compost Mix
Ammonia	3.045 lbs/ton mix
Amines	0.09515 lbs/ton mix
Total Sulfur Compounds	0.1175 lbs/ton mix

18 ibid

TGNMOC	2.41 lbs/ton mix

The proposed ABT-Haskell facility is capable of treating 100,000 tons of wet biosolids over the course of a year. The table below details the maximum emissions for 100,000 tons of wet biosolids being composted assuming no emission controls, 80% emission control (minimum requirement to meet SCAQMD Rule 1133), 95% emission control, 99% emission control, and 99.9% emission control (rated emission control for the ABT-Haskell AirLance™ System). These input values were used to derive ground level concentrations of chemicals potentially being emitted from the facility in the dispersion model.

Table 5.4: Annual Potential Emissions For 100,000 Tons of Biosolids:

	Pounds of Emissions Per Year			
Chemical	80% Control	95% Control	99% Control	99.9% Control
Ammonia	60,900	15,225	3,045	304.5
Amines	1,903	475.75	95.15	9.515
Total Sulfur Compounds	2,350	587.5	117.5	11.75
TGNMOC	48,200	1,2050	2,410	241

6 METEOROLOGICAL DATA

The climate in Los Angeles is characterized by moderate temperatures with comfortable humidities and limited precipitation. Temperatures are normally mild, with rare extremes above 100 °F or below freezing. Mean annual precipitation is approximately 14.5 inches, of which, approximately 12.2 inches occur from November through March.

For modeling purposes, the SCAQMD uses 1981 meteorological data (i.e., hourly winds, temperature, atmospheric stability, and mixing heights) from 35 sites in the district. The 1981 meteorological data are used because this data set represents the most complete and comprehensive data set currently compiled. These data are available at the SCAQMD's web site[19] and are in a format that can be directly read by ISCST3. The closest meteorological data station maintained by the SCAQMD was identified from the posted list of sites.

Table 6.1: Meteorological Data

Station ID			UTM (KM)			
SFc	Upper	City Name	E-W	N-S	Long	Lat
54144	99999	BANNING	510.5	3754.5	116:53:11	33:55:58
54149	99999	FONTANA	455.4	3773.9	117:29:01	34:06:24
54161	**99999**	**REDLANDS**	**486.2**	**3769.4**	**117:09:00**	**34:04:00**

Each data file contains preprocessed meteorological data, formatted into columns; one record per hour. The windrose, or visual display of the windpattern measured at Station 54161, is presented in Figure 6.1. The predominant windpattern in the vicinity of the Site is from the west-northwest during the daytime and from the east during the nighttime.

[19] www.aqmd.gov/metdata

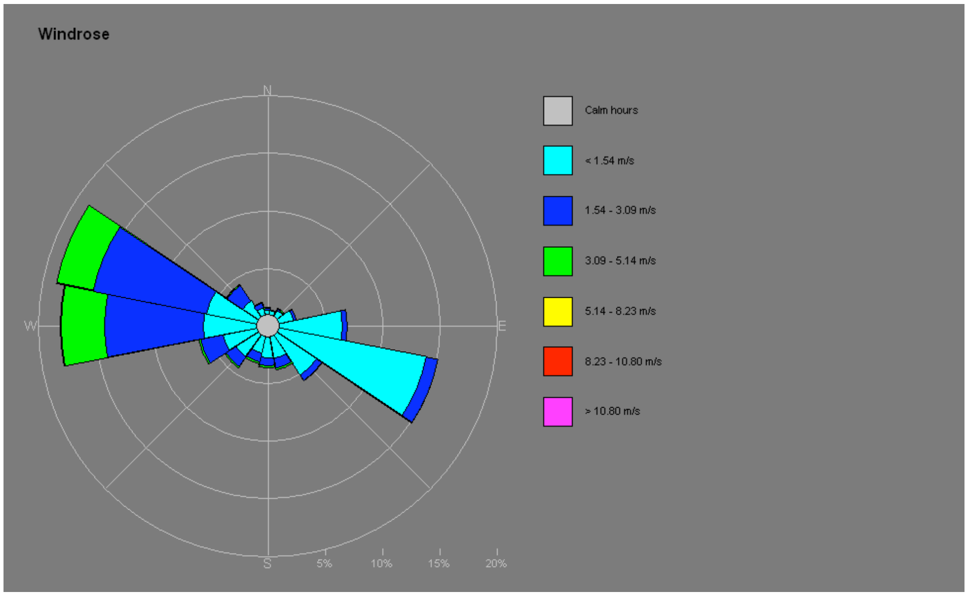


Figure 6.1: Annual Windpattern (Windrose) for Redlands, California

During the winter the predominant wind pattern is dominated by winds from the southeast (counter-current winds from high pressure systems to the west of the Los Angeles Coastal Basin). Frequent rains from December to February dominate the wet season for the Los Angeles Coastal Basin. Stronger winds from the west northwest occur less frequently.

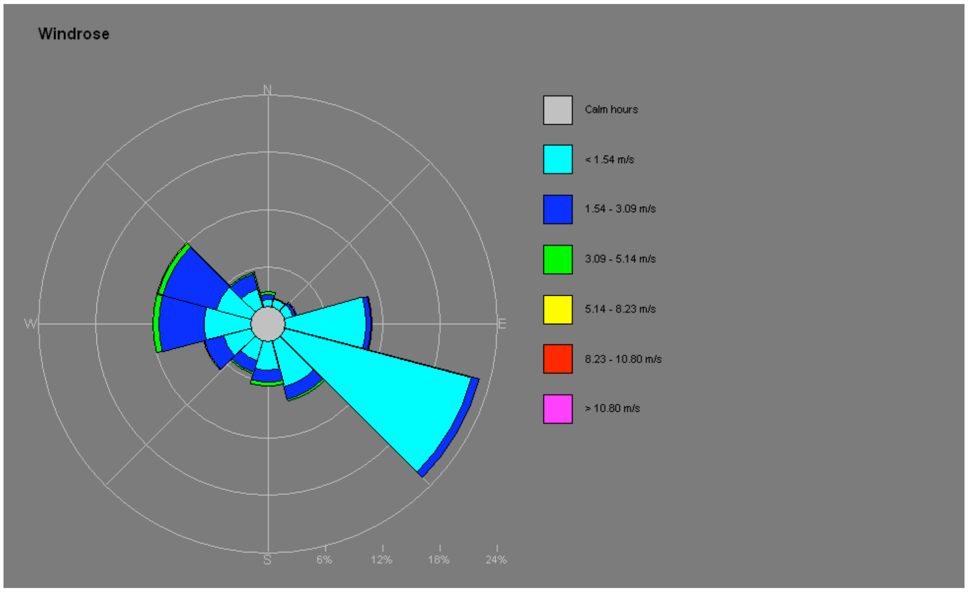


Figure 6.2: Winter Windpattern (Windrose) for Redlands, California

During the spring the predominant wind pattern is dominated by winds from the west-northwest (coastal onshore influence).

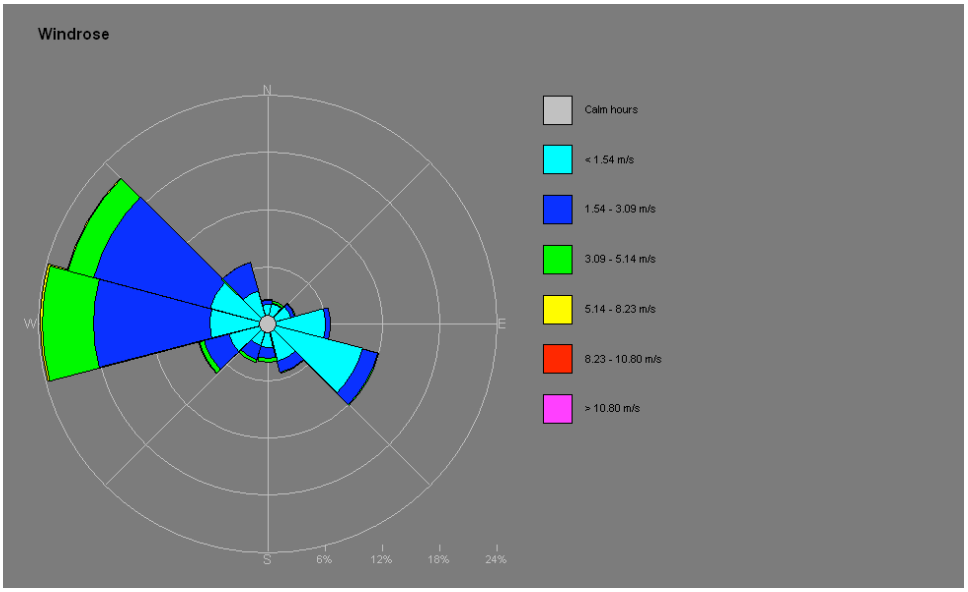


Figure 6.3: Spring Windpattern (Windrose) for Redlands, California

During the summer the predominant wind pattern is dominated by winds from the west-northwest (coastal onshore influence).

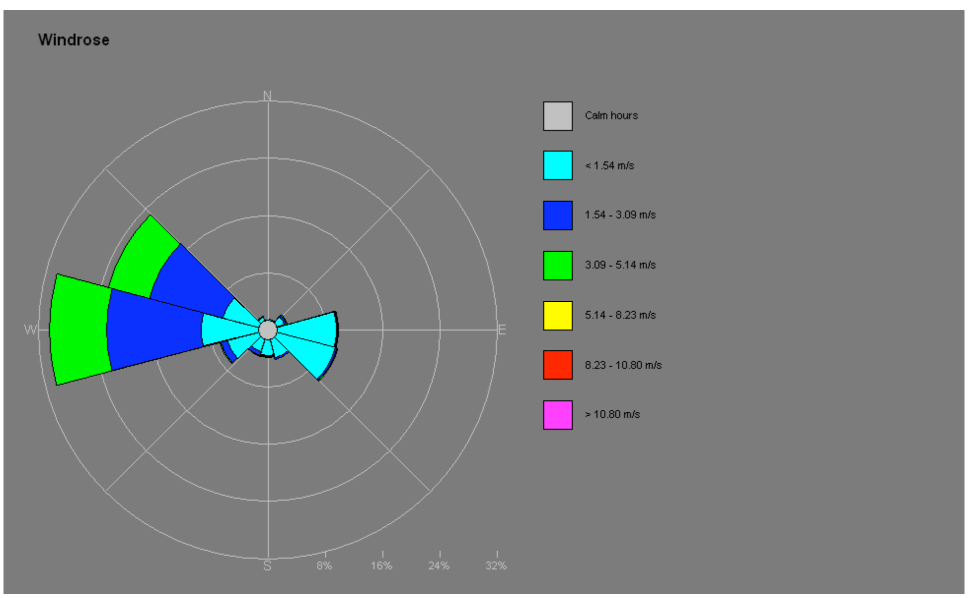


Figure 6.4: Summer Windpattern (Windrose) for Redlands, California

During the fall the predominant wind patterns shift from a strong west-northwest flow to a east-southeasterly flow. This shift highlights the end of the dry season and the start of the winter wet season.

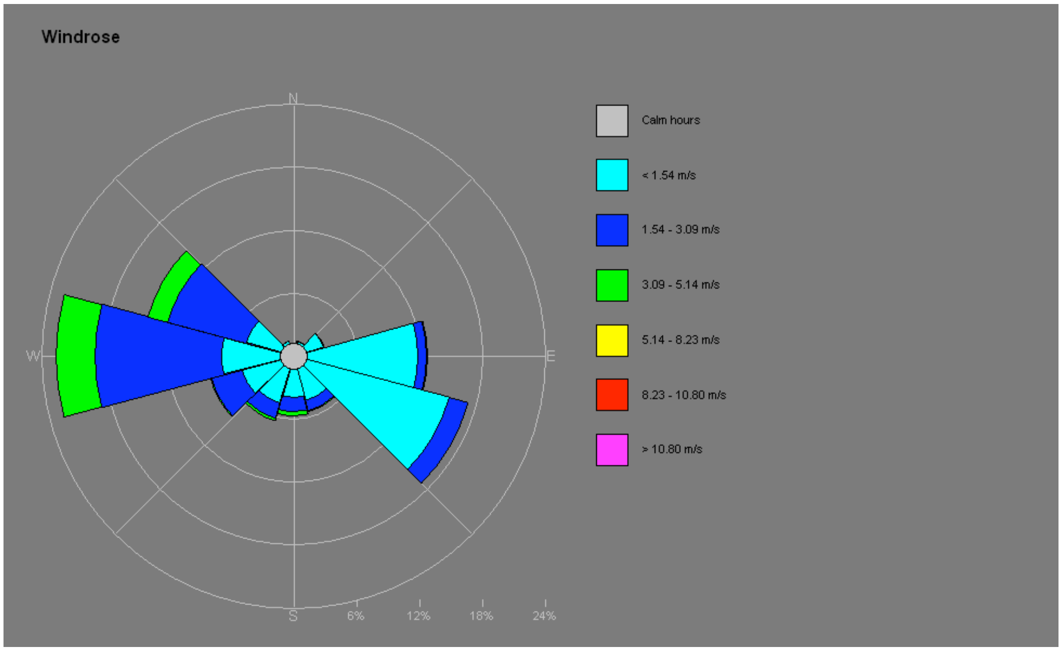


Figure 6.5: Fall Windpattern (Windrose) for Redlands, California

7 ISCST3 MODELING

The Industrial Source Complex-Short Term (ISCST3) model was performed on potential emissions from the ABT-Haskell facility and ground-level concentrations (GLCs) of each compound were calculated for a ½ mile radius of the Site. The model is a steady state Gaussian plume model and is approved by the U.S. EPA for estimating ground level impacts from point and fugitive sources in simple and complex terrain. This model can account for the following: settling and dry deposition of particles; downwash; point, area, line, and volume sources; plume rise as a function of downwind distance; separation of point sources; and limited terrain adjustment. ISCST3 operates in both long-term and short-term modes.

For this study, the dispersion of chemicals was modeled from a point source at the facility. Preliminary designs for the facility show a 54 inch stack from the filtration system exiting at a height of approximately 50 feet above ground surface. The estimated exit velocity for gases from the stack will be approximately 65,000 cubic feet per minute (cfm). Gases were also assumed to be exiting the stack at a temperature of 90 °F. The source terms or concentration of chemicals being emitted from the facility were assumed to be equivalent to the concentrations achieved from 80%, 95%, 99%, and 99.9% control via the previously described scrubber system.

Table 7.1: Annual Potential Tons of Emissions For 100,000 Tons of Biosolids:

			Tons of Emissions Per Year			
Chemical	Tons of Emissions per ton of Compost Mix	Tons of Emissions Without Control	80% Control	95% Control	99% Control	99.9% Control
Ammonia	0.0015225	152	30	7.6	1.52	0.152
Amines	0.000047575	5	1	0.2	0.05	0.005
Total Sulfur Compounds	0.00005875	6	1	0.3	0.06	0.006
TGNMOC	0.001205	121	24	6.0	1.21	0.121

A receptor grid was placed over the system with cells 100 meters by 100 meters. The receptor grid was approximately 3100 meters by 2100 meters in dimension.

Additionally, a fence-line receptor system was set along the property boundary. GLCs were calculated for each of the chemicals, assuming 80%, 95%, 99%, and 99.9% control. The model was run iteratively to determine the maximum 1-hour, 12-hour, and annual average GLCs within the receptor system.

The ISCST3 model output files are presented in Appendix F. Predicted mass GLCs corresponding to the model output values expressed in micrograms per cubic meter (ug/m^3) were derived.

The GLCs were compared to the lowest odor threshold for ammonia as reported by Ruth (1986). Indicator compounds and odor thresholds used in this analysis for amines, sulfur compounds, and TGNMOC are shown in Table 7.2.

Table 7.2: The indicator compounds and the odor threshold

Chemical	Surrogate	Odor Detection Limit
Sulfur	DMDS	0.1 ug/m^3
Amines	TMA	0.8 ug/m^3
Ammonia	NH_3	26.6 ug/m^3
TGNMOC	Phenol	178 ug/m^3

The results of the modeling are presented in Figures 7.1 through 7.49 of the Figure Section.

Sulfur compounds have the lowest odor detection threshold, driving the resulting analysis. While the annual average for the 80% control of sulfur compounds did not exceed the odor threshold on or off the site (Figure 7.10), 1-hour and 12-hour maximums did exceed the odor threshold for receptors on and off-site (Figures 7.2 and 7.6).

For the 95% control scenario of sulfur compounds, the annual average and 12-hour maximum analysis did not exceed the odor threshold for sulfur compounds (Figures 7.11 and 7.7). The 1-hour maximum average did exceed the odor threshold for receptors on and off-site (Figure 7.3).

For the 99% and 99.9% control scenarios, the odor threshold was not exceeded for the annual average, 12-hour maximum, or the 1-hour maximums for receptors on or off-site (Figures 7.4, 7.5, 7.8, 7.9, 7.12, and 7.13).

For amines, ammonia, and TGNMOCs, the analyses show that for all of the control scenarios evaluated (80%, 95%, 99%, and 99.9%) odor thresholds were not exceeded (Figures 7.14 through 7.49).

8 CONCLUSION

The proposed ABT-Haskell facility will be a valuable asset to San Bernardino County in meeting the requirements of AB 939 and will meet the requirements of South Coast Air Quality Management District (SCAQMD) Rule 1133.2.

Dispersion modeling of potential emissions from the proposed facility show that when the system is operational the proposed ABT-Haskell composting facility will have a *de mininus* impact upon the Redlands Community with regard to odor and volatile organic compounds emissions.

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APPENDIX A: SCAQMD RULE 1133.2

APPENDIX B: ODOR DETECTIONS LIMITS RUTH

APPENDIX C: SAN JOAQUIN REPORT

APPENDIX D: EKO REPORT

APPENDIX E: ISCST3 MODEL OUTPUTS

(See attached CD)

FIGURES

ThermoEnergy Corporation

The Sludge-To-Oil Reactor Systems (STORS) is a sludge and wet biomass treatment process that, when combined with the Ammonia Recovery Process (ARP), greatly reduces the regulatory, physical and financial hurdles of building and operating advanced municipal wastewater treatment facilities.
Some of the STORS/ARP process benefits over conventional wastewater treatment methods include:

- **Onsite Conversion of Sludge to High Energy Fuels**
- **Doubles Nitrogen Removal Efficiency**
- **Up to 1,000 Times Smaller Footprint**
- **Equally Effective as Retrofit or New Construction**
- **Significantly Reduces Overall Disposal Costs**

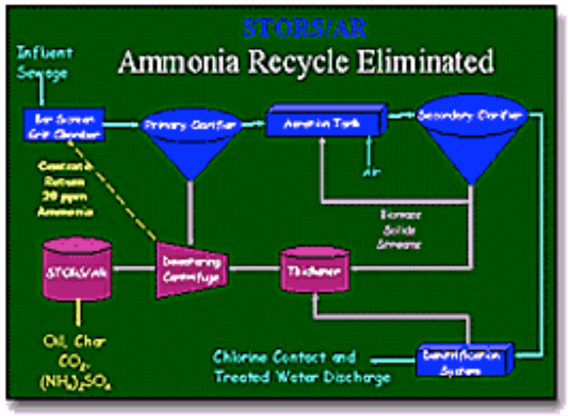
The STORS/ARP process does not vaporize the water in the sludge (as does incineration, pelletization, etc.), but chemically converts sludge organics into oil.

The STORS/ARP Revolutionary New Concept

Dewatered raw, digested or waste activated sludge is processed through a hydrothemal reactor where it is converted into a high-energy fuel in the form of oil or char (the system can be configured to produce whichever fuel has the greatest value within the current market). In addition, some carbon dioxide is formed and discharged along with the excess water. The char, or "Bio-fuel", is one-tenth the volume of the original dewatered sludge and with a fuel value of a medium grad coal (between 5,000 and 10,000 Btu per pound), can be sold to a number of industries as a power source. It can also be used on site to generate electricity to run the facility or sold to the local grid. The oil has 90% of the heating value of diesel fuel and is sent to an off-site user refinery. The carbon dioxide gas is de-odorized and vented. The STORS derived wastewater, along with the centrate stream coming from the dewatering process, is sent to the Ammonia Recovery Process (see Ammonia Recovery Process heading for detailed description) where the nitrogen, in the form of ammonia, is converted into one of three saleable commodities- ammonium sulfate, ammonium phosphate or liquid ammonia - depending on local regulations, and/or whichever product represents the best commercial value for that geographical location.

Small Size - Easy Fit

The STORS/ARP is a component system that can be readily integrated into existing wastewater treatment facilities, freeing up space once used for sludge digestion, storage or staging area for loading on vehicles for off-site disposal. A key factor for large urban areas where additional capacity expansion is desired but the space required by conventional process methods is simply not available. In addition, by installing a STORS / ARP retrofit, many municipal wastewater plant operators can actually realize up to a 30% increase in plant capacity by eliminating the ammonia recycle.



STORS/ARP Process Economics

It has long been said that there are only two drivers in the municipal wastewater industry: compliance and cost. Aside from being the best available technology for achieving or exceeding local, state and federal regulatory mandates, the STORS/ARP process will in most cases, significantly reduce the overall cost of operating a wastewater treatment plant.

As a retro-fit, the STORS/ARP process significantly increases both the available space and process capacity of existing wastewater treatment plants.

ThermoEnergy's goal is three-fold: To achieve "zero discharge" status for municipal wastewater facilities, and to greatly reduce and stabilize the cost of wastewater processing and enhance our nation's energy independence goals. The STORS / ARP process makes this goal a reality.

R & D 100 Award Winner

STORS Large-Scale Demonstration Project

ThermoEnergy Corporation designed, built and successfully operated a five million gallon per day (5 mgd) STORS facility at the Colton, California Wastewater Treatment Plant during 2000. This plant, larger than 75% of municipal wastewater plants in the United States, was operated in conjunction with the Company's ARP process (see Municipal/Agricultural Wastewater

Treatment Systems page). This plant successfully converted raw, digested and waste-activated sludge into a high-energy fuel and ammonium sulfate crystals (fertilizer). This new state-of-the-art facility represents the future in wastewater treatment facilities.

[NitRem | STORS | Ammonia Recovery Process | CAFO]

[Home | Who is ThermoEnergy | Municipal/Agriculture Wastewater Treatment]
[Industrial Wastewater Treatment Systems | Clean Energy Process | Special Technology Applications]
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