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Dust and Airborne Bacteria at Solid Waste Processing Plants

DUST AND AIRBORNE BACTERIA

AT SOLID WASTE PROCESSING PLANTS

This report (SW-773) was prepared
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FOREWARD

This report was prepared for the Municipal Environmental Research Laboratory, U.S. Environmental Protection Agency, Cincinnati, under EPA Contract No. 68-02-1871 to the Midwest Research Institute. It is intended to provide the Office of Solid Waste with a document that may be disseminated to the public so they may be better informed about refuse processing facilities and activities.

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PREFACE--METRIC UNITS

This report has been written using the International System of Units (SI) or metric units. English units in parentheses have been used only occasionally in the report. Most readers are probably familiar with the conversion of feet to meters, cubic feet to cubic meters, and kilograms to pounds. A somewhat more unfamiliar term for large weights is the use of megagrams instead of tons. A megagram is 1,000 kilograms, and a kilogram is 1,000 grams. However, a megagram is only slightly larger than a ton. A ton is approximately 9/10 of a megagram.

The standard unit of time in the SI system is the second. Therefore, airflow rates are expressed in cubic meters per second instead of cubic feet per minute.

In the English system, dust concentrations are usually expressed as grains of dust per cubic foot of air. "Grains" may not be familar to readers except those who work closely with dust control or air pollution. Grains are used because dust concentrations are usually quite small, pounds and ounces are too large a unit of weight to be useful. There are 7,000 grains in a pound. The SI unit most commonly used for dust weight is the milligram, which is 1/1,000 of a gram.

The folloiwng table includes the conversions from SI units to English units for the measures used in this report.

Measure	Multiply Metric SI Units	by	To Obtain English Units
Weight	Megagram (Mg)	1.102	Tons
Air flow	Cubic meters per second (cu m/sec)	21.10	Cubic feet per minute
Dust	Milligrams per cubic meter	0.000437	Grains per cubic foot (gr/cu ft)
Bacteria concentration	Counts per cubic meter (count/cu m)	0.0283	Counts per cubic foot (count/cu ft)

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DUST AND AIRBORNE BACTERIA AT SOLID WASTE PROCESSING PLANTS

Municipal solid waste (MSW) has for years been collected by the familiar "garbage truck" and hauled to sanitary landfills. Occasionally waste transfer stations are used where MSW from small collection trucks is unloaded and then reloaded into larger trucks for transport over long distances to a landfill.

In the early 1970's, the concept emerged that MSW was not altogether a waste material but contained valuable resources. Resource recovery plants where MSW is processed into a refuse-derived fuel (RDF) are now in operation in several cities and more are being planned.

St. Louis and Ames

The first RDF plants were at St. Louis, Missouri, and Ames, Iowa. The St. Louis facility was a demonstration project supported by three cooperative parties: the Environmental Protection Agency (EPA), the City of St. Louis, and Union Electric Company. The project was completed in 1975, and the plant is no longer operated. The Ames plant is an ongoing commercial facility owned and operated by the City of Ames, Iowa.

The above plants are similar, and each is typical of the RDF process: the MSW is reduced in size by a shredder or hammermill, and the shredded MSW is "air classified" to separate the paper and plastic combustibles (RDF) from the nonflammable "heavies." Metals such as ferrous (i.e., contains iron or steel) scrap are removed magnetically and sold as by-products. The air-classified combustible material (RDF) is combine-fired with coal in electric utility boilers. RDF is usually 10 to 25 percent of the total fuel requirement, with coal constituting the remainder.

The St. Louis plant used a single shredder and was an unenclosed plant with all the processing equipment located outside. By contrast, the Ames plant is completely enclosed with all the processing occurring inside a metal building. Ames also uses double shredding where two shredders are installed in series to accomplish size reduction. At St. Louis, the air flow from the air classifier was discharged directly to the atmosphere, while at Ames the air discharge is recycled into the plant.

The Dust Problem

When MSW is shredded, a small portion of the MSW becomes very fine particulate or dust. This dust tends to be fibrous or linty and is similar in appearance to the dust collected by a household vacuum cleaner. Because it is light and fluffy, this dust is easily blown about if not contained. Therefore, at both St. Louis and Ames, dust has been a problem.

St. Louis. Figure 1 is a flow diagram of the St. Louis plant. Refuse collection trucks discharged their loads onto a concrete tipping floor inside a building. The tipping floor is where the refuse collection trucks discharged their loads. The refuse was pushed by a front-end loader onto a conveyor belt feeding a shredder. Shredded refuse was carried by a conveyor belt to the air classifier, and the air-separated RDF was carried by another conveyor belt to a storage bin. This RDF was removed from the storage bin and carried by a conveyor belt to a packer station where large trucks were loaded for transporting the RDF to the power plant. There the RDF was combine-fired with coal in an electric utility boiler. Heavier (reject material) from the air classifier was carried by a conveyor belt to a magnetic separator where ferrous metal was removed and sold for scrap.

Fugitive Dust. The cause of the ambient dust problem at the St. Louis plant can be attributed to: (1) exhaust from the air classifier cyclone collector; (2) shredder operation; (3) spillage from conveyors.

In air classifier, shredded MSW is fed into an upward moving stream of air which lifts and carries the lighter portion of the MSW with it while the heavier material falls downward. A cyclone separator is used to separate the "lifted" material (RDF) from the air stream. At St. Louis, the air exhaust from the cyclone was vented directly to the atmosphere. Cyclone separators have been used for many years, and their principles of operation are well known. Their removal efficiency is quite high on large particles. Therefore, at St. Louis, the air classifier cyclone exhaust carried with it small particles of dust. Tests conducted to measure the rate of the air classifier cyclone dust emissions showed the average emission rate to be 27 kg/hr (60 lb/hr). As this discharged dust was already airborne, it was quickly blown about the plant area.

The shredder at St. Louis was a large hammermill with a horizontal shaft fitted with large swinging hammers. MSW entered the shredder from the top and was torn apart by the action of the hammers until it was small enought to fall through square grates in the bottom of the shredder. The action of the hammers inside the shredder created a "windage effect" which tended to blow dust out of the mill. To reduce the dust discharge, the conveyors to and from the shredder were enclosed, and the shredder was fitted with a small fan and cyclone collector as a partial dust collection system.

Spillage resulted from all the various plant operations, especially when equipment was cleaned for routine maintenance or when breakdowns occurred. Waste material, whether it was shredded MSW, RDF, heavies, etc., contained dust which was easily blown about the area. Also, small pieces of paper and plastic bags present in the spillage were picked up by air currents and blown about. The net result was fugitive dust around the plant area.

Cleanup. At St. Louis, processing was conducted only during the regular day shift. During the second shift, a two-man crew was used to clean the area. Part of the work was to open and clean out the equipment (primarily the shredder). However, some labor was required to cleanup the fugitive dust at the plant. Because the immediate plant area was black-topped, a large water hose was used to clean the equipment' and the surrounding area.

Complaint by a Neighbor. Even though the cleanup work was the best that could be expected under the circumstances, the plant received complaints from an adjoining neighbor, an industrial storage depot. This resulted in the air classifier exhaust air being ducted to a large settling chamber fitted with a plastic mesh screen. This helped, but did not eliminate, the fugitive dust problem.

Ames. The Ames facility is still an ongoing municipal plant. Figure 2 is a flow diagram of the Ames plant which is very similar to the St. Louis plant; however, there are several major differences. Ames uses two shredders with magnetic separation between the first and second shredders; a pneumatic conveying system is used to deliever the RDF to the storage bin; and an aluminum separation system is used.

Ames has the same type of fugitive dust problems as St. Louis had, except no neighborhood complaints have been received because all the processing equipment is enclosed within a building. Therefore, little fugitive dust escapes to the surrounding neighborhood. The exhaust air from the air classifier is recycled to the air classifier air intake. While no dust is exhausted out of the building, this recycling increases the dust level within the plant.

Cleanup and Working Conditions. Like St. Louis, Ames uses a cleanup crew. Because the dust is confined within a building, the dust is more concentrated, resulting in undersirable working conditions. Some plant employees wear dust masks when working for long periods within the processing area.

Mechanical Problems. The outdoor plant at St. Louis was cleaned by the rain and by periodic washdown with a water hose. At Ames, the plant is enclosed and was not designed for washdown. Therefore, the dust within the Ames plant may have a greater probability of harming motors and bearings and of clogging equipment air filters.

Dust Control. After two years of operation, the City of Ames decided that a plant dust collection system was needed. Plant personnel anticipate

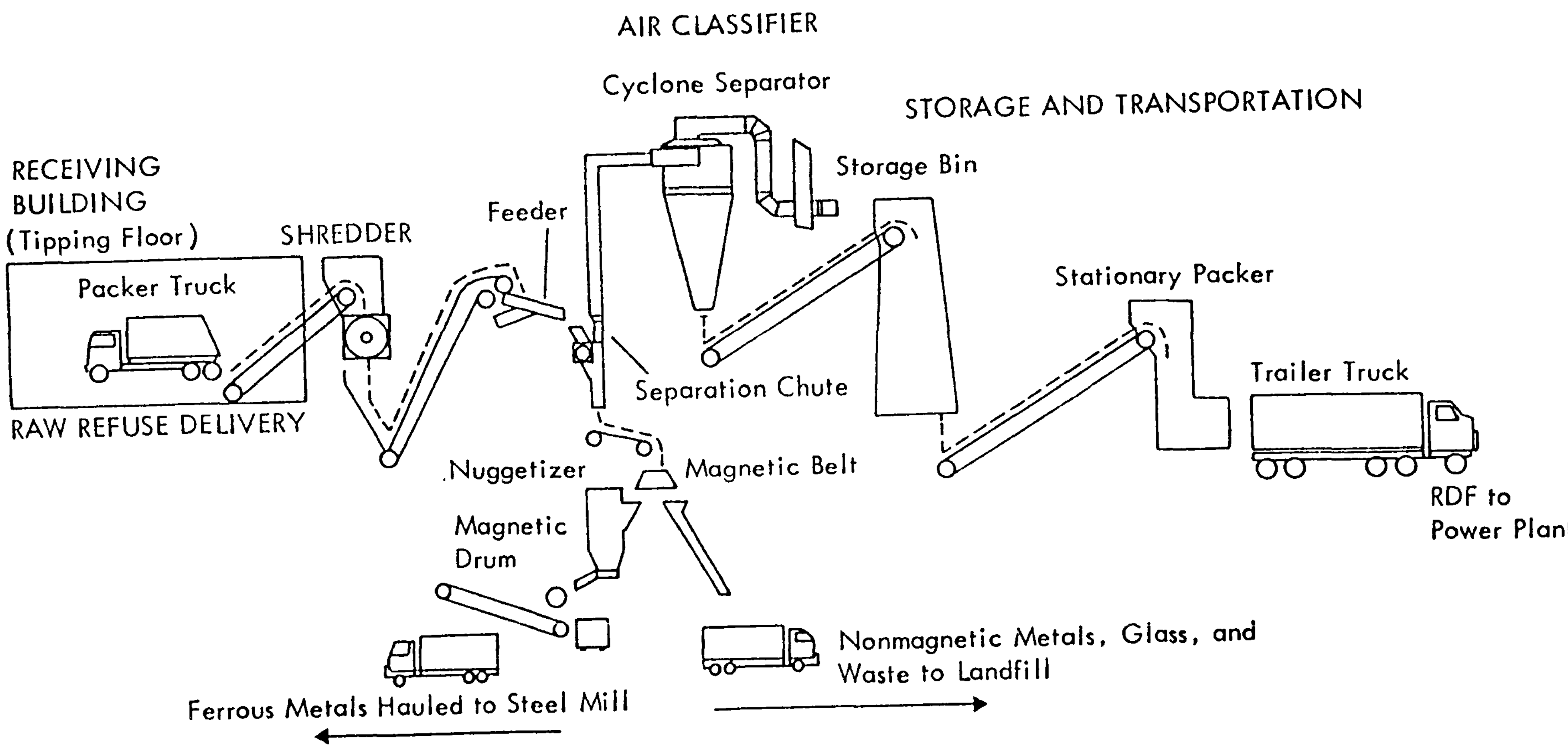

Figure 1 - Flow diagram of St. Louis RDF plant

that this dust collection system will reduce plant costs by reducing cleanup labor and equipment maintenance.

Other Problems

Other problems that may be traced to fugitive dust in RDF Plants are fire hazard and airborne microorganisms.

Fire Hazard. The fire hazard due to the accumulation of dust around RDF plants is a serious problem.

The dust is readily flammable because it is generated mainly from flammable paper and plastic. Both the St. Louis and Ames plants have had several fires. One fire at Ames caused a shutdown of 10 working days. It was believed to have started in an accumulation of dust and spillage beneath one of the shredders. One of the important justifications for the Ames dust collection system was reduction of the fire hazard.

Microorganisms. A great many microorganisms such as fungi, bacteria, virus, and protozoa exist in MSW, some of which are beneficial to man and some of which are harmful. Microorganisms are certain to be associated with MSW processing plants. Incomplete studies suggests that many are not free floating in air but are carried along on dust particles generated when MSW is processed into RDF. Control of this dust should help control microorganisms that may be present.

Test Programs

At both St. Louis and Ames, test programs were conducted to measure the amount and type of microorganisms that existed in and around RDF plants. These tests were made to determine if a health hazard existed and to provide more information for better plant designs and systems to control dust emissions.

Dust Measurement. Extensive dust emission measurements were made at St. Louis to describe the amount and size of the dust at various locations around the plant. An interesting discovery was that the fugitive dust has a higher energy content (heating value) than RDF itself and, therefore, has an economic value which is lost if the dust is allowed to escape.

Microorganisms. Extensive measurements were conducted for bacteria. Although standard dust measurement methods are well known and have been thoroughly published in reference documents, the measurement of airborne bacteria carried by dust in and around waste processing facicilities was a pioneering effort by the Environmental Protection Agency. Very little previous work has been done in this area.

Dust Collection Systems

Others have benefitted from the St. Louis and Ames experiences, resulting in improved designs of RDF plants and the use of very efficient fabric filtration to eliminate dust at its source. Plants where dust collection was incorporated in the original plant design include Milwaukee, Wisconsin; Chicago, Illinois; and Rochester, New York. A discussion of dust collection by filtration along with design considerations and cost information are presented in a later section.

DUST CONCENTRATIONS

Solid Waste Processing Plants Tested

To date, dust measurements have been made at the following four plants: (1) St. Louis, Missouri--RDF demonstration plant; (2) Houston, Texas--Shredder plant using an experimental air classifiers; (3) Appleton, Wisconsin--Shredder plant; (4) Cockeysville, Maryland--RDF research plant.

The St. Louis plant has been described in the previous section. The Appleton plant is similar to St. Louis except no air classifier is used. Only shredding and magnetic separation are employed, and the shredded MSW, less the recovered ferrous metal, is landfilled. The Houston plant originally was identical in design to the Appleton plant (i.e., only shredder and magnetic separator); however, for test purposed a new style of air classifier was installed. The Cockeysville plant produces RDF, utilizing shredding, air classification, screening, and magnetic separation. This plant is used as a research facility by a private firm.

Unfortunately, dust emissions measurements had not been made at the Ames plant, at the time these data were prepared.

Test Procedures

The amount of dust present in the air was measured by passing a known amount of air through a filter which collects the dust. The clean filter was carefully weighed before the test. After the test, this same filter, now dirty with dust, was again weighed. The difference between the two weights is the amount of the dust collected.

Two types of samplers were used. The first is termed a "Hi-Vol" sampler. Using this device, a fan pulls a high volume of air through a filter. This sampler is used to make measurements of the ambient air inside the plant such as at worker locations.

When air is exhausted through a duct (as in a dust control system), a second type of smapler was used which is called a "Method Five" sampler,

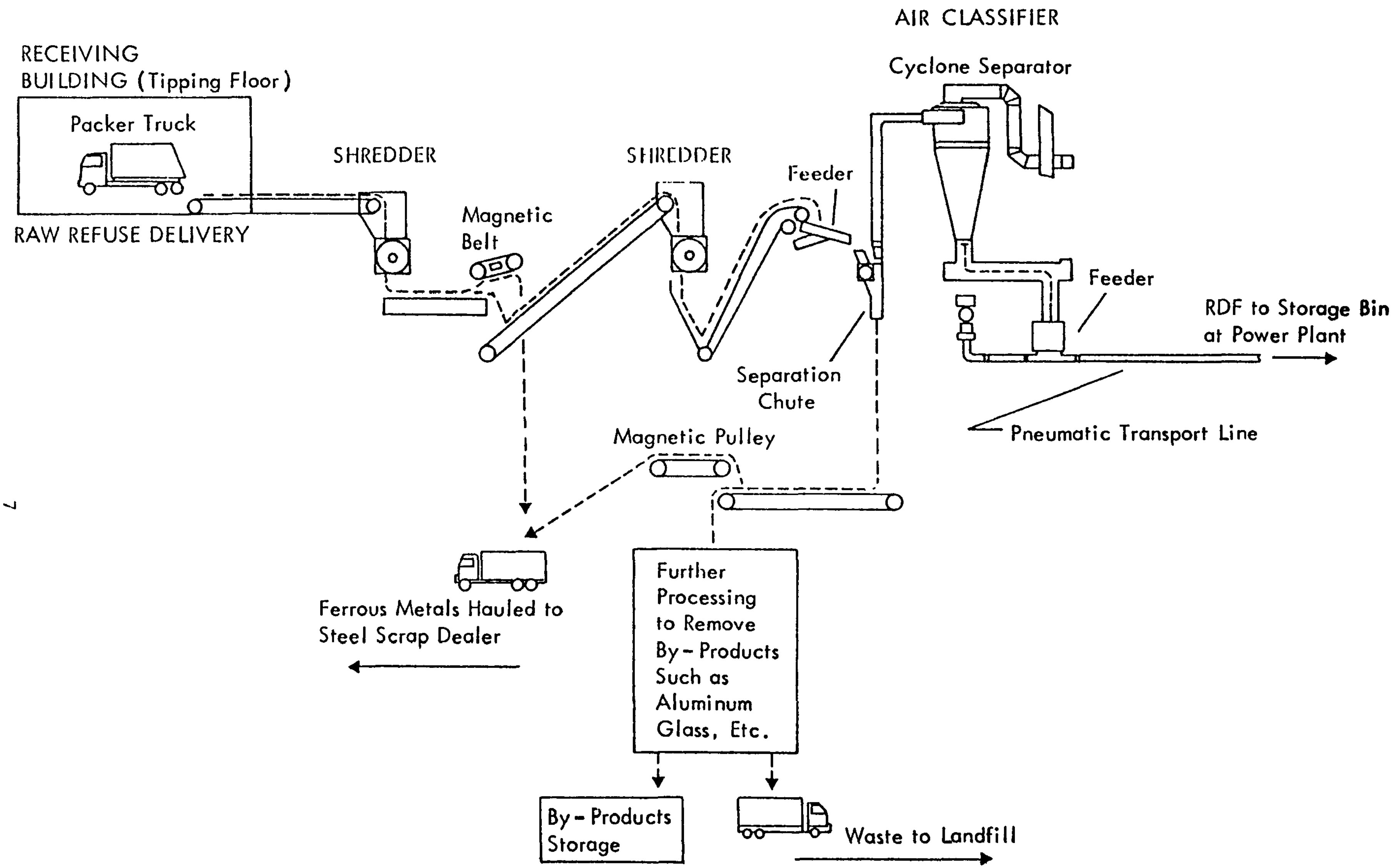

Figure 2 - Flow diagram of Ames RDF plant

named after the EPA reference method. This sampler also pulls air through a filter, using a vacuum pump, but a probe, which is a steel tube, is used to reach inside the air duct to draw a sample. The dust collected, or dust catch, is the dust deposited on the filter and any dust that may have settled out in the sampling probe. This dust is carefully removed from the probe and weighed along with the filter deposit.

In both methods, the dust weight is known, and the volume air sampled is known. This will yield, through calculations, the weight of dust per unit volume of air. In the metric system, the units are milligrams per cubic meter.

Dust Concentration Test Results

Dust measurements were made at the four different MSW processing plants (Table 1). The values are averages from several measurements made at each location and are expressed in metric units. The air flow rate from the St. Louis and Houston air classifiers and the St. Louis dust collector cyclone on the shredder were also measured (Table 2). The remaining locations were at various places within the plants; therefore, there is no airflow rate associated with these locations.

The dust concentration in the air exhaust from the Houston Air classifier settling chamber was much higher than the St. Louis air classifier cyclone exhaust because a settling chamber is much less efficient than a cyclone. However, the air from this settling chamber was not exhausted directly to atmosphere.

The air was first routed to a fabric filter which removed virtually all the remaining dust before the air was vented to the atmosphere. This fabric filter is discussed in a later section. The exhaust from the St. Louis air classifier was cleaned by a cyclone collector which has a higher dust removal efficiency than a settling chamber; however, the air from this cyclone was exhausted directly to atmosphere without additional cleaning by a fabric filter.

The dustiest in-plant location at St. Louis was at the top of the RDF storage bin. This bin was enclsoed, with a walkway at the top where a belt conveyor discharged the RDF into the bin.

The in-plant locations at Appleton and Cockeysville had dust concentrations within the same order of magnitude, ranging in round numbers, from 1 to 6 mg/cu m. It is very interesting to observe that of these in-plant locations, the tipping floor at Appleton was the dustiest and the tipping floor at Cockeysville had the lowest dust concentration. In both plants, the trucks backed up to a holding pit into which the MSW was discharged from the collection trucks. However, there were differences in truck traffic patterns in and out of the tipping floor and differences in the size and layout of the pits. Also, the tipping floor at Appleton was relatively open to the rest of the

Table 1

DUST MEASUREMENT RESULTS

Plant	Location	Average dust concentrations mg/cu m
St. Louis	Exhaust from air classifier cyclone	571
	Exhaust from shredder dust collection system cyclone	738
	Inside walkway at top of RDF storage bin	17.5
Houston	Exhaust from air classifier settling chamber (prior to a fabric filter)	23,000
Appleton	In-plant sites:	
	Tipping floor	5.6
	Next to the shredders	3.5
	Next to the magnetic separator	1.4
	Next to shredded MSW belt discharge	3.4
Cockeysville	In-plant sites:	
	Tipping floor	1.1
	Next to the shredder	2.9
	Next to the magnetic shredder	1.7
	Insider process building which houses an air classifier and a large screen separator	3.1

Table 2

AIR FLOW MEASUREMENT RESULTS

Plant	Location	Airflow cu m/sec	(cu ft/min)
St. Louis	Exhaust from air classifier cyclone	13.3	(28,000)
St. Louis	Exhaust from shredder dust collection system cyclone	0.5	(1,100)
Houston	Exhaust room air classifier settling chamber	21.8	(46,000)

plant area, while at Cockeysville the tipping floor was separated by a wall from the rest of the plant area.

There is closer agreement between plants for dust concentrations around the shredder and the magnetic separator. The dust concentrations shown in Table 1 are averages of from three to eight measurements per location. Individual measurements vary from the averages, showing that dust concentrations are not consistent at any given location. It is expected that dust emissions vary with such factors as the moisture content of the MSW, the composition of the MSW, and the plant processing rate. The most important conclusion is that significant dust concentrations exist at the MSW processing plants tested.

BACTERIA CONCENTRATIONS

Measurements were made to determine the concentration of bacteria per unit volume of air. For dust alone, various standards have been set so that judgements can be made concerning the potential harmfulness of various dust concentrations. However, actual numbers of bacteria are relatively meaningless in determining whether or not a potential health hazard exists because no standards have been established for airborne bacteria. Since bacteria will most likely be present whenever solid waste is handled, other waste handling plants were tested. This at least allows comparisons to be made between the bacteria concentrations at an RDF plant and the concentrations at other similar plants.

Solid Waste Processing Plants Tested

The facilities tested in this research program were: (1) RDF plant--St. Louis; (2) municipal incinerator; (3) solid wste transfer station; (4) sanitary landfill; (5) muniicpal wastewater (sewage) treatment plant.

Following is a brief description of each of the five plants tested.

Refuse-Derived-Fuel. The St. Louis RDF plant has been described in the previous section. Airborne bacteria measurements were made at the following locations: (1) upwind and downwind from the plant along the property boundaries; (2) tipping floor where the refuse collection trucks unload; (3) operator control room; (4) packer station where large trucks are loaded with RDF; (5) air classifier exhaust.

Incinerator. At the incinerator, incoming refuse trucks are weighed on a platform scale adjacent to a dump pit. After weighing, the trucks discharge MSW into the dump pit at one side of a tipping floor. The MSW is picked up from this pit by an overhead crane and deposited in charging hoppers, which in turn feed several combustion chambers where the MSW is burned. Measurements were made at the following locations: (1) upwind and downwind from the plant along the property boundaries; (2) scale room; (3) tipping floor; (4) overhead crane.

Waste Transfer Station. The waste transfer station has a large tipping floor very similar to the RDF plant where the refuse collection trucks discharge their loads. The MSW is then pushed by a front-end loader into a hopper feeding a packer. At the packer, a large hydraulically operated ram pushes the MSW into a large truck. Three packer stations are located at the end of a truck ramp. These particular packer stations are almost identical in operation to the one used at the RDF plant. The large truckloads of MSW are then hauled several miles to a sanitary landfill. Measurements were made at the following locations: (1) upwind and downwind from the plant along the property boundaries; (2) tipping floor, north side; (3) tipping floor, east side; (4) truck ramp, packer station location.

Sanitary Landfill. The tested landfill is a traditional operation where trucks enter the area, are weighed on a platform scale, and then proceed to a designated area (working face) where they discharge their loads of MSW. Measurements were made at the following locations: (1) upwind and downwind from the landfill working face along the property boundaries; (2) scale; (3) working face, west side; (4) working face, east side.

Wastewater Treatment Plant. At the wastewater treatment plant sewage is first received in three primary settling basins. The seage next goes to an aeration basin where air is injected into the sewage. From there the sewage flows in sequence to two secondary settling basins, a sludge thickener, holding tanks, and lastly to a large press where remaining liquid is squeezed from the solids. The solids removed by the press are burned in an incinerator. Measurements were made at the following locations: (1) upwind and downwind from the plant along the property boundaries; (2) primary settling basin; (3) aeration basin; (4) press room, operators area; (5) press room basement.

Amount of Waste Handled at Each Point. Waste handling facilities vary greatly in size. The five plants were selected to be as close as possible in size to provide better comparisons. The total amount of waste material received at each plant was recorded on each day of testing. The average amounts are shown in Table 3.

For the plants handling MSW, the weights shown are the total received for the day since the plants receive refuse during only one shift per day which corresponds to the sampling period. However, the sewage treatment plant received sewage 24 hr/day. The average liquid amount of 2,067,000 liters is received during the 6 to 7 hr period when samples were taken. This liquid volume converts to approximately 2,000 megagrams (2,200 tons) on a weight basis.

Table 3

AMOUNT OF WASTE HANDLED AT TEST PLANTS

Plant	Averaged daily amount of waste material received during the test period			
	Megagrams	(Tons)	Litters	(Gallons)
RDF plant	163	(180)		
Incinerator	340	(375)		
Waste transfer system	311	(343)		
Sanitary landfill	788	(869)		
Wastewater treatment plant			2,067,000	(546,000)

Other Bacteria Measurement Locations. For the purpose of making comparisons, measurements were made at two other special locations. The first special location was the back of a garbage truck. Two samplers were attached to the back of the truck, one on each side, and were powered by a generator attached beneath the truck. The purpose of this sampling location was to determine the bacteria concentrations in the area where workers are collecting MSW from city residences and placing it in the refuse collection truck.

The second location was in the city of St. Louis where a sampler was set up on the corner of a major downtown intersection. The purpose of this location was to determine background concentrations of bacteria, where heavy pedestrian and vehicle traffic was present, in the same city as the RDF plant. This was an important sampling point for comparative purposes. Airborne bacteria concentrations are not normally zero in nature; however, they would be expected to be relatively low in rural and suburban areas. Therefore, a realistic background location for comparative purposes is a busy street corner in a metropolitan city like the one in downtown St. Louis.

Microorganisms Measured

An objective of the research program was to look for harmful species that might exist in MSW. A detailed work plan was prepared and submitted to a panel of 10 experts in this field. As a result of this work plan and the expert review comments, nine criteria were selected: (1) total aerobic bacteria; (2) salmonella bacteria; (3) staphylococcus areus bacteria; (4) total coliform bacteria; (5) fecal coliform; (6) feca; streptococcus bacteri; (7) klebsiella bacteria and viruses; (8) adeno-viruses and (9) enteroviruses.

Total aerobic bacteria, which is bacteria that can exist in air, was measured to determine the total amount of airborne bacteria that was present. Likewise, virus was measured to determine the amount of virus that was present. Salmonella, staphylococcus, streptococcus, and klebsiella were measured because these are pathogens (disease-causing bacteria species). Coliforms are bacteria that exist in the intestinal tract of man and animals, and forms which resemble or are related to them. Although not generally pathogens themselves, they indicate that undesirable fecal material may be present. "Total coliform" refers to a group or family of bacteria while "fecal coliform" is a species occurring in several varieties within this groups.

Test Procedures

The field sampling procedures were much the same as for dust. Hi-Vol samplers, as described in an earlier section, were used to draw air through a filter which collected the dust. At the end of each test day, the filters were removed from the samplers, sealed and packed in an ice chest, and shipped to the laboratory. Analysis of the filters began the next day.

The laboratory procedures used were relatively complex. Briefly, the dust-laden filters were processed into a slurry (or "paste") and the slurry was placed onto a nutrient culture media. The samples were then incubated. The number of bacteria that had grown were counted, differentiating between different species. A detailed technical discussion of the methods used is contained in the report "Assessment of Bacteria and Virus Emissions at a Refuse Derived Fuel Plant and Other Waste Handling Facilities."*

The volume of air sampled through each filter was measured, and the bacteria concentration per unit volume of air was calculated. In the metric system, results are expressed in bacteria counts per cubic meter of air, and in the English system, results are in units of bacteria counts per cubic foot of air.

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* Fiscus, D. E., P. G. Gorman, M. P. Schrag, and L. J. Shannon. Assessment of Bacteria and Virus Emissions at a Refuse Derived Fuel Plant and Other Waste Handling Facilities. U.S. Environmental Protection Agency Report EPA-600/2-78-152. Municipal Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio, August 1978. 240 pp.

Microorganism Test Results

No salmonella, staphylococcus, or virus was found in any of the samples collected. Klebsiella was found in only four samples and at very low levels. Therefore, the comparison between waste processing plants was made for the following four bacteria types: (1) total bacteria count; (2) total coliform; (3) fecal coliform; (4) fecal streptococcus.

Bacteria concentrations varied at each measurement location, which is not surprising since it is known that dust concentrations also vary from day to day at MSW processing facilities. Two facts must be kept in mind concerning the measured bacteria concentrations. Since bacteria are living organisms, and the laboratory analysis of field samples did not begin until the day after the samples were collected, bacteria could have multiplied, or more likely died off, even when every precaution was taken. Therefore, the bacteria concentrations in counts per cubic meter of air should not be considered as absolute values. Nonetheless, all plants were measured in the same way, and the data are useful in making comparisons between plants.

The following discussion includes the ranges of average bacteria concentrations found and a comparison or ranking of the various plants. Because a great number of measurements were made, statements concerning the comparison of one plant to another will be more useful and more easily understood than voluminous and complicated tables and graphs of individual measurement numbers.

Range of Bacteria Concentrations. The range of average concentrations by category is shown in Table 4.

These values are the ranges of the average results. Of course, some individual measurements were above and below these average values. Fecal streptococcus concentrations were higher than were the coliform concentrations.

These values are the ranges of the average results. Of course, some individual measurements were above and below these average values. Fecal streptococcus concentrations were higher than were the coliform concentrations.

The downtown bacteria concentrations fell within the range of concentrations upwind from the plants, and as expected, the downwind concentrations tended to be higher than the upwind concentrations. An important result for comparative purposes is that the refuse collection truck samples had higher average concentrations of total collection truck samples had higher average concentrations of total coliform and fecal coliform than any of the waste processing plants.

Table 4

RANGE OF BACTERIA CONCENTRATIONS

Location in category	Average bacteria concentrations (counts/cu m) Total bacteria count	Total coliform	Fecal coliform	Fecal streptococcus
Upwind at property line				
High	8,000	1	0.2	15
Low	500	0.09	0.02	1
Dowtown				
High	2,200	0.5	0.15	1.5
Low	950	0.25	0.03	1
Downwind at property line				
High	20,000	60	2	55
Low	500	0.12	0.02	1
In-plant				
High	400,000	100	11	2,170
Low	220	0.03	0.05	1
Packer truck (refuse collection truck)				
High	90,000	300	170	460
Low	55,000	210	110	410

In summary, while some small values of bacteria counts per cubic meter found, there were also some large values measured. All locations had measurable amounts of total bacteria, total coliform, fecal coliform, and fecal streptococcus. The next step then is to determine how the individual plants compared to one another.

Waste Processing Plant Comparisons. Table 5 gives a ranking of the various plants, including downtown and the packer truck, from highest to lowest average bacteria count.

Some trends become apparent from this ranking. The RDF plant had higher downwind concentrations than any of the other plants, but it also had higher upwind concentrations. Therefore, it becomes difficult to claim that the RDF plant caused a greater increase in downwind bacteria levels than other types of waste handling facilities. Surprisingly, the downtown location did not have the lowest bacteria concentrations when compared to plant downwind locations. Depending on the bacteria measured, either the wastewater treatment plant, the waste transfer station, the sanitary landfill, or combinations of these three plants had lower concentrations.

Table 5

RANKING BASED ON AVERAGE BACTERIAL LEVELS IN DESCENDING ORDER FROM HIGHEST TO LOWEST CONCENTRATION

Total bacteria count	Total coliform	Fecal coliform	Fecal streptococcus
	Ambient samples--upwind (and downwind)		
RDF plant	RDF plant	RDF plant	RDF plant
Incinerator	Downtown	Downtown	Incinerator
Downtown	Incinerator	Waste transfer	Waste transfer
Waste transfer	WWTP	Incinerator	Downtown
WWTP*	Waste transfer	WWTP	WWTP
Landfill	Landfill	Landfill	Landfill
	Ambient samples--downwind (and downtown)		
RDF	RDF plant	RDF plant	RDF plant
Incinerator	Waste transfer	Waste transfer	Incinerator
Downtown	Incinerator	Incinerator	Waste transfer
WWTP	Landfill	WWTP	Downtown
Waste transfer	Downtown	Downtown	WWTP
Landfill	WWTP	Landfill	Landfill
	In-plant samples		
RDF plant	Packer truck	Packer truck	Waste transfer
Packer truck	RDF plant	RDF plant	Packer truck
Incinerator	Waste transfer	Waste transfer	RDF plant
Waste transfer	Incinerator	Incinerator	Incinerator
WWTP	Landfill	Landfill	Landfill
Landfill	WWTP	WWTP	WWTP

* WWTP = Wastewater treatment plant.

For the in-plant locations, the refuse collection packer truck had higher total coliform and fecal coliform concentrations than the RDF plant. Comparing the RDF plant to the other waste handling facilities, the RDF plant had higher in-plant bacteria levels for total bacteria count, total coliform, and fecal coliform than the other plants. However, the waste transfer station had higher fecal streptococcus levels than the RDF plant. The incinerator wastewater treatment plant and the landfill had lower in-plant concentrations than the RDF plant for all four bacteria types measured.

The conclusions from these test results is that the RDF plant tended to have higher in-plant bacteria concentrations than many, but not all, of the other facilities tested. However, the RDF plant tested was a plant with only a rudimentary dust collection system. If a well-designed dust collection system were used, then bacteria levels in an RDF plant would be expected to be comparable to, or less than, levels in other waste handling facilities. Fortunately, the justification for dust collection is not based on bacteria control alone. In addition to reduction of bacteria levels, there is also a need for dust collection systems to reduce the dust levels in RDF plants. Regardless of any bacteria concentratins, dust removal would be very beneficial to RDF plants because there are many other problems associated with dust such as fire hazards, plant maintenance and cleanup, etc., which would also be ameliorated.

DUST COLLECTION SYSTEMS

Dust collection systems for RDF plants were relatively simple and were composed of only three major parts as follows: (1) the dust capture hoods and connecting duct work; (2) the air-moving fan and motor; (3) a fabric filter, commonly called a baghouse.

Suction is provided by the fan to pull into the capture hoods. The baghouse then filters virtually all the captured dust from the airstream which is exhausted to atmosphere. In a very rough sense, a dust collection system is a large vaccum cleaner.

Baghouses, fans, duct work, and capture hoods come in a variety of configurations. The most important consideration is correct design and placement of the capture hoods because a very efficient baghouse will do an RDF plant no good if the dust is not first captured. For persons interested in more technical details, an excellent discussion of dust collection is presented in the book, Industrial Ventilation.* Competent engineering services should always be used in the design of dust collection systes. "Do-it-yourself" dust collection systems have seldom proved adequate.

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* Industrial Ventilation, American Conference of Governmental Industrial Hygienists, P.O. Box 453, Lansing, Michgan 48902 (manual updated periodically; request latest edition if ordering).

Collection Efficiency

Baghouses are very efficient for the type of dust found in RDF plants. EPA has tested two baghouses. One was a small-scale baghouse at the St. Louis RDF plant where a portion of the air classifier exhaust air was drawn from the exhaust duct and passed through the baghouse. The second was a full-scale baghouse, cleaning the total exhaust from the air classifier settling chamber used at the Houston shredder plant. At both locations, measurements of dust and bacteria concentrations were made before and after the baghouses so that their collection (removal) efficiency could be determined.

Dust Collection Efficiency. Table 6 gives the dust collection efficiency for the two baghouses.

Table 6

DUST COLLECTION EFFICIENCIES

Plant	Average dust concentration before the baghouse (mg/cu m)	Average dust concentration after the baghouse (mg/cu m)	Collection efficiency (%)
St. Louis	300	0.154	99.95
Houston	23,000	2.76	99.99

These two tests are quite interesting to compare because the concentration of dust in the inlet to the baghouse was quite different at the two locations. At St. Louis, the air to the baghouse was the exhaust air from the air classifier cyclone separator. As discussed earlier, this cyclone separator removed much of the dust from the air classifier. The Houston facility merely had a settling chamber installed immediately prior to the baghouse which allowed large pieces of RDF to drop out of the air stream but still allowed the fine material to pass on to the baghouse. Therefore, the Houston baghouse had a much heavier dust concentration in the incoming air.

The important point is that even though the dust concentrations were very different, the removal efficiency of the baghouse was almost the same, being better than 99.9 percent efficient. The high efficiency of baghouses on dust from RDF plants was expected, based on a study of various published reports describing baghouses used to collect different types of dusts.

Bacteria Collection Efficiency. The baghouses were also very efficient in collecting bacteria, as would be expected, because it is believed that bacteria are carried by dust particles. Therefore, the theory is that if the dust is collected, the bacteria are also collected. However, even if bacteria are not associated with dust particles, a baghouse should still removed them very well since baghouses yield high removal efficiencies on bacteria-size particles. following is the bacteria collection efficiency efficiency for the St. Louis and Houston baghouses. Efficiencies are given in Table 7 for total bacteria and for the individual species.

The bacteria collection efficiency for the Houston baghouse was slightly less than the dust collection efficiency. However, the bacteria efficiency is still very high, being better than 98 percent.

Table 7

BACTERIA COLLECTION EFFICIENCIES

Plant	Average baghouse collection efficiency for bacteria (%)			
	Total bacteria count	Total coliform	Fecal coliform	Fecal streptococcus
St. Louis	99.60	99.99	99.95	99.91
Houston	98.87	98.65	98.39	98.20

Design Considerations

Dust can be controlled in an RDF plant in a variety of ways. The traditional dust collection system with capture hoods, suction air, and fabric filtration is used to collect dust as it is being emitted. However, it is often preferable to keep the dust from being emitted in the first place.

Belt conveyors are commonly used in RDF plants. These can be partially covered to reduce dust emissions. The most important locations to control are the loading and discharge points of the conveyor, because at these points the MSW, RDF, etc., are agitated most, creating the dustiest conditions. However, the plant designer should also consider other types, such as screw conveyors and drag conveyors which can be totally enclosed. If the covers and their loading and discharge spouts are tight-fitting and sealed, then screw or drag conveyors should have very low dust emissions.

Another area requiring dust control is storage bins. When material falls into a storage bin, the material replaces the air in the bin. This escaping air can carry small dust particles with it. Storage or surge bins, especially for shredded MSW or RDF, should be covered and the bin vents should be conveniently located for the dust control duct work.

A technique which has been used effectively in other industrial plants, and which may have application to RDF plants, is to enclose dusty areas. This technique helps to keep dust confined to one or a few areas and prevents contamination of the rest of the plant.

Building ventilation is a very important consideration for the design engineer. Most RDF plants will have a heating and air conditioning system providing air for plant offices, operator control rooms, and employee locker rooms and lunchrooms. Furthermore, in plants where air classifiers and dust collection systems are used, air will be drawn from inside the plant and exhausted outside the plant after passing through a baghouse. This exhausted air must be made up by admitting air into the plant through fresh air intakes. The fresh air intake for heating and air conditioning, ventilation, and makeup plant air should be located as far as possible from any dusty air exhausts. The cleaner the air entering the plant, the easier will be the task of keeping the plant clean.

Recirculation of dirty air within the plant should also be avoided. At the Ames facility, the exhaust air from the air classifier was recirculated into the plant. This was a good idea for eliminating emissions to the outside atmosphere. However, even though this exhaust is introduced into the plant near the air classifier air intake, a certain amount of dust escapes and contaminates the surrounding plant area. At Ames, a baghouse was installed on the air classifier air exhaust.

Worker protection is another aspect of dust management. Obviously workers should have clean and well-kept locker room and lunchroom areas. However, personal protectin devices such as dust masks, etc., should be available if the plant has especially dusty areas.

For any individual plant, it probably will not be possible to control all dust emissions without the use of a dust collection system, which will be discussed next.

Dust Collection and Filtration. Not all plant locations need dust collection, because dust is not generated at all locations. Use of enclosed conveyors and enclosed storage bins, for example, can sharply reduce the need for dust collection. The philosophy of dust collection is that it be employed wherever dust is being generated. Solid waste lying at rest does not produce dust. Only when it is moved about is dust produced. Visual observations in RDF plants indicate that shredded MSW and RDF are the greatest dust contributors. The various recovered metal by-products and reject material, such as air classified heavies, are generally not large contributors to the plant dust burden.

Following is a list of plant locations that should be carefully considered for application of dust collection: (1) shredder inlet and outlet; (2) any open conveyor transfer point; (3) unenclosed screening devices used to screen or clean MSW or RDF; (4) storage and surge bin vents; (5) air exhaust from an air classifier; (6) air exhaust from a pneumatic conveying system.

Because it has high energy value, the dust collected by a dust control system should be combined with the RDF.

Also, because dust in RDF plants is flammable, fire detection and protection systems are important considerations for the designer and the plant management. Containers of gasoline, cartons of aerosol cans, etc., may be found in MSW and have, in the past, resulted in shredder explosions. Therefore, explosion venting and explosion suppression may be a necessary part of plant design.

Cost of a Dust Collection and Filtration System. Costs vary with the size of an RDF plant. The 1978 cost a dust collection system at Ames, Iowa, a nominal 45 megagrams per hour (50 ton/hr) RDF plant, was $166,000. This is the total installed price including engineering, materials, fabrication, and installation.

The dust collection system includes a baghouse on the air exhaust from the air classifier cyclone and dust collection hoods within the plant area.

Various engineering estimating methods are available to arrive at dust collection cost estimates. These methods range from "rule of thumb" methods to very detailed and specific cost quotations. Of course, the more information that is available concerning any plant, the more accurate will be the cost estimate.

Fortunately, dust collection costs are available for two RFD plants: Ames, Iowa, and Monroe County, New York. Both dust collection systems were installed in 1978, so cost comparisons may be made without adjusting for the value of the dollar in different years. Costs for material, labor and engineering is: (1) Ames--$166,000; (2) Monroe County--$992,000.

These costs do not include the cost of financing and start-up. The engineering portion of the cost for Monroe County is an estimate.

Since these two plants are very different in size, the question is how can the dust collection costs for these plants be compared and how can they be used to predict costs for other plants? Dust emissions probably depend on the processing rate because it is reasonable to assume that the more MSW that is processed per hour, the greater is the potential for dust emissions.

The Ames facility ws built and operated for approximately two years before the decision was made to install a dust collection system. Therefore, the dust collection system was designed to control the actually observed emissions resulting from the actual processing rate, not the original design processing rate. The actual processing rate for the Ames plant, calculated from plant data, is 23 megagrams per hour (25 tons/hr). This value is calculated from the actual amount of MSW processed over several months divided by the total actual hours the plant conducted processing (not including cleanup and maintenance hours after processing had ceased). The Monroe County plant is not yet in operation, but it is planned to operate at an actual 63.5 megagrams per hour (70 tons/hr) for each of two processing lines. Therefore, the total Monroe County plant processing rate is 127 megagrams per hour (140 tons/hr). These data allow rule-of-thumb calculations to be made in Table 8.

Table 8

DUST COLLECTION COSTS

Plant	Dust collection cost	Processing rate Mg/hr	Processing rate (ton/hr)	Cost per processing rate $/Mg/hr	Cost per processing rate ($/ton/hr)
Ames	$166,000	23	(25)	7,217	(6,640)
Monroe County	$992,000	127	(140)	7,811	(7,085)

These rule of thumb estimates are in relatively close agreement. The Monroe County cost in terms of dollars per processing rate is approximately eight percent more than for Ames. This eight percent difference is most likely due in part to differences in plant design and layout, and labor rate differences between Iowa and New York.

In summary, a rough order of magnitude (ROM) estimate in round figures is $8,000 per megagram/hour, yielding $360,000 for a 45 megagram per hour (50 tons/hr) plant. This estimated cost is only for materials, labor, and engineering.

In addition to labor, materials, and engineering, there are many other items in the overall cost: financing, maintenance equipment and spare parts and supplies, contingencies, and start-up expense. Most of these can be amortized over the life of the equipment. The yearly operating cost would then include the amortized cost, utilities, insurance, management, and administrative labor, maintenance labor, and maintenance supplies. Table 9 illustrates a simplified cost model used to develop yearly costs of a dust collection system.

The financial model of any individual plant will, of course, vary from the simple model shown here. In summary, cost of a dust collectin system for an RDF plant would range from $0.50 to $0.75 per megagram ($0.45 to $0.67/ton), based on 1958 data. No attempt has been made here to estimate the cost savings resulting from: (1) decreased plant cleanup labor; (2) decreased plant maintenance; (3) cleaner environment inside and outside the plant; (4) reduced plant insurance costs due to reduced fire hazard; or (5) reduced plant downtime due to fires.

Table 9
DUST CONTROL COST MODEL

		1978 ($)
Capital investment		
Equipment, installation, and construction management		330,000
Design engineering about 10%		30,000
	Subtotal	360,000
Financial charges at 25% (interest during construction, bond underwriting, legal costs, etc.)		90,000
Spare parts and maintenance equipment about 5%		18,000
Start-up expense about 10% (includes acceptance testing)		36,000
Contingencies about 10%		36,000
	Total capital investment	540,000
Yearly cost		
Depreciation assuming 20-year straight line write-off		27,000
Operation and maintenance		
Direct labor about 1/3 man-year/year*		5,000
Supervision about 1/10 man-year/year†		2,000
Utilities about 1.3% of capital investmant each year		7,000
Maintenance supplies about 0.7% of original captial investment each year		4,000
Overhead absorption about 0.35% of original captial investment each year		2,000
	Total	47,000

Yearly cost per megagram of MSW processed

Assume 240 days/year (260 weekdays less 20 days for holidays and plant downtime) at 7 hr/day; 45 mg/hr yields 75,600 megagrams (83,400 tons)/year	About 0.6/Mg (About 0.55/ton)

* A man-year of direct labor is assumed to cost $15,000.
* A man-year of supervision is assumed to cost $20,000.

The financial model of any individual plant will, of course, vary from the simple model shown here. In summary, cost of a dust collection systems for an RDF plant would range from $0.50 to $0.75 per megagram ($0.45 to $0.67/ton), based on 1978 data. No attempt has been made here to estimate the cost savings resulting from: (1) decreasd plant cleanup labor; (2) decreased plant maintenance: (3) cleaner environment inside and outside the plant; (4) reduced plant insurance costs due to reduced fire hazard; or (5) reduced plant downtime due to fires.

SUMMARY

Processing plants that produce refuse derived fuel (RDF) by shredding the combustible materials in municipal solid wastes are in operation in several locations. Dust is a problem whenever the wastes are agitated, including (a) the tipping floor where trucks are unloaded, (b) open areas of conveyors, (c) shredders, and (d) cyclone separators.

Main corrective measures are: (1) containing the dust, by using covers on conveyors, and by using walls to separate the dustiest areas from cleaner areas of the plant; (2) providing dust masks where workmen must enter any dusty area; (3) preventing exhaust of dirty air into outdoor atmosphere; (4) designing and installing bag filters to capture the dust before it escapes from the processing equipment.

Efficiency of the bag filter systems was over 99.5 percent in capturing dust, and over 98 percent in capturing bacteria.

Bacteria count in processing plants for refuse-derived fuel ranged from 220 to 400,000 counts per cubic meter (cu m), compared to outdoor atmosphere range of 950 to 2,200 counts per cubic meter at a downtown location.

Total coliform bacteria airborne inside the plant ranged from 0.03 to 100 counts/cu m, compared to outdoor downtown range of 0.25 to 0.5 counts/cu m. Fecal coliform bacteria ranged from 0.05 to 11 counts/cu m inside the plant, and 0.03 to 0.15 outdoors downtown. Fecal streptococcus ranged from 1 to 2,170 counts/cu m inside the plant, and 1 to 1.5 counts/cu m outdoors downtown.

The dust measurements were made at refuse-derived-fuel plants at St. Louis, Missouri; Houston, Texas; Appleton, Wisconsin; and Cockeysville, Maryland. Bacteria concentrations were measured at the St. Louis plant and for comparison, at an incinerator site, solid waste transfer station, sanitary landfill, and municipal sewage treatment plant.

Typical costs for designing and installing dust control systems in large and small plants producing refuse derived fuel from muncipal solid wastes were estimated, based on 1978 data.

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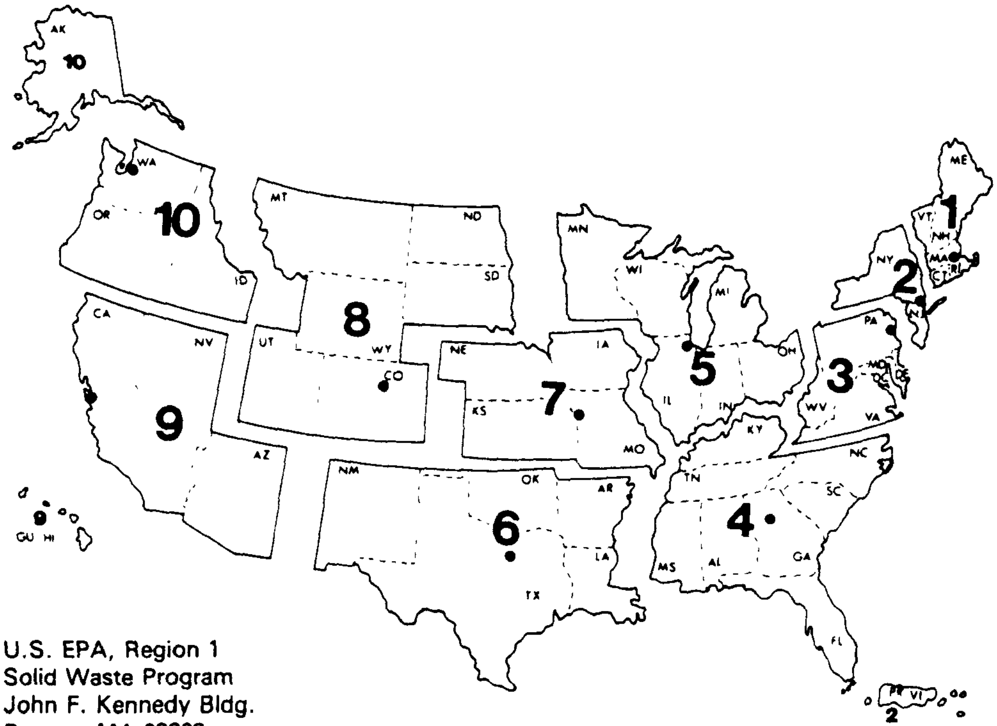

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