FINAL REPORT

INTENSIVE RECYCLING FEASIBILITY STUDY FOR THE CITY OF BUFFALO

April 15, 1988

CBNS

CENTER FOR THE BIOLOGY OF NATURAL SYSTEMS
QUEENS COLLEGE, CUNY FLUSHING, NEW YORK

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INTENSIVE RECYCLING FEASIBILITY STUDY FOR THE CITY OF BUFFALO

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SUMMARY

Under the terms of a contract between the Common Council of the City of Buffalo and Citizen Action-New York, the Center for the Biology of Natural Systems (CBNS) has studied the feasibility of applying the CBNS Intensive Recycling System to the disposal of household trash in Buffalo.

The present Buffalo trash disposal system is based on collection of unseparated trash from households and small commercial establishments by the City Department of Street Sanitation (DOSS). At present the collected trash is delivered to transfer stations at a cost to the City ("tipping fee") of $20 per ton. However, this fee is expected to rise sharply, because the landfills and the incinerator in which Buffalo trash is ultimately disposed are becoming more costly in response to the new, more rigorous regulations that their serious environmental hazards require. If the City continues its present trash disposal system, it will probably face a tipping fee of about $60 per ton in 1991, which will continue to rise thereafter. The average landfill tipping fee in the Northeast already reached $39 in 1987.

The CBNS Intensive Recycling System can provide the City with a cost-effective means of trash disposal that avoids the environmental hazards inherent in trash-burning incinerators and that sharply reduces landfilling. It differs from the present Buffalo trash disposal system in several important ways:

- Householders are required to separate trash into four containers; three contain recyclable fractions of the trash (food garbage and yard waste; paper and cardboard; bottles and cans),

and the fourth contains non-recyclables. The containers are brought to the curb for weekly pickup.

• The separate fractions are collected by two truck-trailer units. The food/yard waste fraction is taken to a facility that converts it into marketable compost; the paper/cardboard and bottle/can fractions are taken to a materials recovery facility that produces marketable commodities: several grades of paper, color-separated crushed glass, aluminum and tin cans. The non-recyclable fraction can be disposed of in an ordinary landfill.

In assessing the feasibility of applying this system to trash disposal in Buffalo, we have made the following determinations:

1. A CBNS test of the Intensive Recycling System (of 100 households over a 10-week period) in East Hampton, L.I., shows that it can recover 84% of the trash (by weight) in marketable forms. Because of this high level of physical efficiency, the Intensive Recycling System can serve as an alternative to incineration (which burns about 70-75% of the trash, by weight).

2. A survey of a total of 514 households in three Buffalo neighborhoods (Delaware, Fillmore and Masten) shows that about 78% of the households would be willing to do the necessary separation of trash. There was no significant difference in the level of positive response among these three neighborhoods, which differ in their socio-economic character; together they are representative of the total Buffalo population. This result, together with the high physical efficiency of intensive recycling, indicates that

the system can effectively dispose of the city's total stream of regular trash.

3. The markets for the recycled products produced by the Intensive Recycling System that are accessible to the Buffalo area have been evaluated. They are sufficiently large to readily accommodate the system's output of recycled materials.

4. The environmental impact of the Intensive Recycling System is minimal; the processing facilities do not appear to emit unacceptable amounts of dust or toxic metals; they do not emit toxic chemicals or pathogenic microorganisms. They are free of the toxic hazards generated by trash-burning incinerators.

5. The Intensive Recycling System is cost-effective, as compared with the City's present system. In 1991, with the new system in full operation, its annual net cost to the City would be $118.81 per ton, about 4.5% less than the total cost of the present system ($124.42) -- assuming a $60 per ton tipping fee and a 90% rate of household participation). As the tipping fee rises above $52.47 per ton, the Intensive Recycling System becomes progressively less costly than the present one.

The total cost of the Intensive Recycling System and the break-even tipping fee will be reduced below this estimate if the prices received for recycled materials are at the high end of the reported range rather than the mid-point. If the prices are at the low end of the range, if pickup time is increased (relative to the present system) by 50% rather than 25%, or if there is no increase in overtime, then the break-even tipping fee increases.

6. Adoption of the Intensive Recycling System would significantly increase employment and earnings of DOSS workers, as

compared with the present system. Employment would increase from 311 in the present system to 374 in the proposed system; total employee annual earnings would rise from $8,306,500 in the present system to $11,560,600 (computed in constant 1987 dollars) in the proposed system -- an increase of $3,254,100, or 39.2%.

7. A considerably larger portion of the funds spent by the City to operate the Intensive Recycling System would remain within the Buffalo economy as compared with the funds spent to operate the present system. As a result, adoption of the proposed system would significantly increase the positive impact of the City's trash-disposal expenditures on the Buffalo economy. Construction of the new processing facilities would involve 243 temporary jobs, with earnings of $4,266,000 and increased industrial output of about $14,023,000 (computed in constant 1987 dollars). In addition to this one-time-only impact, operation of the proposed system would have an appreciable ongoing economic impact; annual industrial output would increase by $4,592,000, employment by 139 jobs, and earnings by $4,550,000. Moreover, by pioneering in the application of intensive recycling to urban trash disposal, the City would create opportunities for the local development of new industries that process recovered materials and produce recycling-related equipment and supplies.

8. We conclude that the adoption of the Intensive Recycling System would provide the City with a means of trash disposal that, compared with the present one, would significantly reduce city trash disposal costs; would increase the number of DOSS employees and their total earnings; and would appreciably increase the

positive economic impact of trash-disposal spending on the City's economy.

In order to implement the proposed Intensive Recycling System, we recommend that the City undertake a small-scale pilot test (involving 50-100 volunteer households), followed by a larger mandatory test (involving one or more neighborhoods or 1,000-10,000 households). The tests should be trials of the Intensive Recycling System -- that is, four-container separation and processing of all recyclable trash fractions -- in order to refine the procedures and assumptions used in this feasibility study. Such tests would provide more precise information about the composition of the trash stream; the rate of trash production; the adequacy of household containers; and the appropriate sizes of the collection vehicles. These data refinements are important, for they will influence the overall cost of the system. When the second pilot test is undertaken, it will be necessary for the City to commit itself to full-scale operation of the Intensive Recycling System, for the test will require the construction of the necessary processing facilities.

I. INTRODUCTION

Environmental impacts and rising costs have created a national trash-disposal crisis. Landfills, which now receive 90% of the nation's trash, have created serious environmental problems and, in any case, are rapidly filling up. The New York State Dept. of Environmental Conservation (DEC) expects to close more than two-thirds of the state's present landfills, and will soon announce new rules severely restricting their operation (NYS DEC, 1987a). Regulatory legislation is under consideration as well. These trends, which recognize the environmental unsuitability of landfills, are reflected in the costs paid to dispose of trash in them ("tipping fee"); the national average fee has nearly doubled between 1982 and 1987 (Pettit, 1988). Tipping fees in the Northeast are particularly high, doubling between 1986 and 1987; the average tipping fee was $39 per ton in 1987.

Trash-burning incinerators face similar difficulties. They generate very serious environmental and health hazards in the form of toxic emissions and ash, and new, more expensive environmental control systems are being introduced. As a result, incinerator tipping fees have increased sharply, rising on the average by 160% between 1982 and 1987 nationally (Pettit, 1988). Since the incinerator's environmental problems are still unresolved, these costs are expected to rise further.

The trash disposal crisis will have a serious impact on the City of Buffalo. After being collected by the City, Buffalo's trash is delivered to transfer stations where NEWCO, a subsidiary of Browning-Ferris Industries (BFI), takes responsibility for final disposal, in return for a tipping fee of approximately $20 per ton (City of Buffalo, 1987). This compares well with the national average tipping fee at landfills ($20.36) or incinerators ($33.64) (Johnson, 1988). On the other hand, the ultimate disposal of Buffalo's trash, chiefly in the Occidental incinerator at Niagara Falls, contributes to the environmental hazards generated by that facility.

It is clear, however, that the present situation will not last very long and that Buffalo faces sharp increases in costs if the present trash disposal system is not changed. The City contract with BFI must be renegotiated this July. The company has already stated that it will replace the present three-year contract with a one-year contract. There are indications that BFI will demand a significantly higher tipping fee -- apparently more than $30 -- and that further increases will be required in subsequent years. This expectation reflects the trash disposal problem in Erie and Niagara Counties. About 90% of the Buffalo trash is carted by BFI to the Occidental Chemical Co. incinerator in Niagara Falls and the remainder is deposited in the company's Erie County landfills. Both the landfill and incinerator costs are expected to increase not only because of their generic environmental difficulties, but also because of situations peculiar to them.

Competition for local landfill space is becoming progressively more acute. Two of the landfills in the Erie-Niagara region are municipally owned; these are expected to close in the near future. The BFI landfill in Tonawanda is also expected to close, and that town expects to face a nearly doubled tipping fee when it shifts to another landfill or disposal system. This problem is compounded by the fact that the remaining two landfills accept 65% and 35% of their trash respectively from outside the area (MacClennan, 1988); since they are privately owned, they are free to do so. Because landfills are being rapidly closed in New York and New Jersey, those in the Erie-Niagara region are being used increasingly by distant communities. For example, Essex County, NJ, expects to ship incinerator ash to an Erie County landfill (Curcio, 1987). So, because of heavy demand for the diminishing landfill space in the Erie-Niagara region, the costs of trash-disposal in a landfill will rise at an increasingly rapid rate.

A similar situation affects disposal in trash-burning incinerators. According to the recent Waste Age tipping fee survey (Pettit, 1988; Johnson, 1988) the Occidental plant, which receives most of Buffalo's trash, charged a fee of $15 per ton in 1986. Currently the fee is $25 (Eggers, 1988), and it is certain to increase further. One reason is that the Occidental incinerator has been required to make extensive improvements in emission controls as a result of a 1985 test conducted by DEC that revealed unacceptable emissions of particulates and dioxin. Although subsequent tests in 1987 showed that particulate emissions were apparently in compliance with State standards, the new dioxin emission values are not yet available. If they fail to improve, the plant may face additional costs for control equipment. Occidental plans to pass these costs through to the tipping fee (Eggers, 1988).

Incinerator ash disposal is also likely to generate increased costs. The Occidental plant, which burns about 600,000 to 700,000 tons of trash annually, generates about 150,000 tons of ash per year (Eggers, 1988). At present the ash is deposited in a local landfill. However, recent DEC tests of ash from six New York State incinerators (not including Occidental) show that the ash frequently contains so much toxic lead and cadmium as to fall under the EPA definition of a "hazardous substance," which must be disposed of in a special (and very costly) hazardous waste landfill (NYS DEC, 1987b). Despite these results, DEC has thus far refused to designate the ash in this way and has declared that it is a "special substance" that can be disposed of in a special kind of "monofill" landfill (Nosenchuck, 1988). This will nevertheless require higher costs for the disposal of the Occidental plant's ash. If the DEC's redefinition of the ash's toxicity is withdrawn and the ash must go to a hazardous waste landfill, the disposal costs will become extremely high. (There is pressure in this direction; a bill currently before the Suffolk County Legislature would require incinerator ash disposal in a hazardous waste landfill. In addition, EPA is being sued by the Environmental Defense Fund to require that incinerator ash be designated as a hazardous substance.)

Thus, the cost of disposing of trash at the Occidental incinerator is bound to increase rapidly. Moreover, the continuing availability of the plant is uncertain. For example, depending on the as-yet-unreported dioxin emission levels found in the last DEC test of the plant, Occidental might be required to add a scrubber to the control system. The cost of the scrubber would not only add $10-$20 per ton to the tipping fee, but installing it might involve a lengthy shut-down of the plant (Manoogian, 1988; City of NY Dept. of Sanitation, 1984)

It is apparent that the present costs of disposing of Buffalo trash, whether in a regional landfill or the Occidental incinerator, are almost certain to rise considerably. Based on the foregoing considerations, we estimate that the present tipping fee will increase by about three-fold in the next three years.

These considerations require that the City of Buffalo plan for a new system of trash disposal that sharply reduces its present dependence on landfills and the Occidental incinerator. Intensive recycling is a way of accomplishing this purpose. Intensive recycling can dispose of the City's trash without incurring the environmental hazards involved in incineration; it sharply reduces the amount of trash that is landfilled or incinerated. As tipping fees rise over the next few years, it will become the City's most cost-effective means of trash disposal. In this report we present the results of our study, under a contract from the Buffalo Common Council, to evaluate the feasibility of applying intensive recycling to the Buffalo trash problem as a means of providing the City with a cost-effective, environmentally sound means of solving it.

II. BACKGROUND

Municipal solid waste consists of residential, commercial and institutional trash. Almost all of Buffalo's commercial and institutional trash is picked up and disposed of by private carters. This report is concerned with the trash stream that is collected and disposed of by the City: trash from residences and some small commercial establishments that are part of the city's regular collection system.

This trash stream is composed of "regular" waste (for example, food garbage and yard waste, paper, cardboard, bottles and cans) and "bulky" waste (such as discarded appliances, furniture, tires and large branches and, in the fall, leaves). As shown in Table I, such bulky waste represents about 19% of the total trash stream; it is picked up by special city collections, while the regular trash is picked up at weekly intervals. These two parts of the trash stream must be handled differently. The bulky waste is normally landfilled; a good deal of it could, however, be salvaged for reuse or recovery. The regular trash, which makes up the greater part of the trash stream, can be either landfilled, incinerated, or recycled. This project analyzes the feasibility of using a system of intensive recycling to dispose of the regular part of the residential trash stream.

About 85% (by weight) of the residential trash stream consists of components that are currently capable of being recycled: paper and cardboard into recycled paper and paper products; aluminum and tin cans into aluminum and steel; glass bottles and jars into crushed glass used in manufacturing glass products; food garbage and yard waste into compost (see Appendix A). There are two approaches to recycling these components: (1) partial recycling, and (2) intensive recycling. Although this study is concerned with the feasibility of applying intensive

Table I

ESTIMATED BUFFALO WASTE STREAM (1987)

	Total Waste (t/mo)	Bulky Waste (t/mo)	Regular Waste (t/mo)	Regular Non-yard Waste (t/mo)	Yard Waste (t/mo)
January	11,781	770	11,011	10,560	451
February	10,373	835	9,538	9,538	0
March	14,568	3,000	11,568	10,560	1,008
April	15,838	3,000	12,838	10,219	2,619
May	17,929	4,526	13,403	10,560	2,843
June	19,750	5,212	14,538	10,219	4,319
July	17,792	3,910	13,882	10,560	3,322
August	16,305	3,692	12,613	10,560	2,053
September	16,785	2,802	13,983	10,219	3,764
October	15,943	2,657	13,286	10,560	2,726
November	14,265	2,991	11,274	10,219	1,055
December	13,096	1,456	11,640	10,560	1,080
Annual Total	184,425	34,851	149,574	124,335	25,239
% of Total	100%	18.9%	81.1%	67.4%	13.7%
Annual Average lb/person-day	3.16	0.60	2.56	2.13	0.43
June Peak:					
tons per day	658	174	485	341	144
lb/person-day	4.11	1.09	1.09	2.13	0.90

Assume:

1. Total waste refers to waste picked up by City of Buffalo crews. It consists of almost all residential waste plus material from small commercial establishments. Bulky waste consists of furniture, white goods, and some yard waste, e.g., leaves in the fall. "Regular waste" is defined as total waste minus bulky waste. Regular waste refers to the elements of the trash stream collected weekly by the Dept. of Street Sanitation.
2. Generation of regular non-yard waste (total minus bulky minus yard waste) is constant <u>per day</u> and equals the generation rate of regular waste during February (i.e., no yard waste in Feb.). Therefore, the amount of regular residential waste generated per day is about 340.6 tons per day. Waste generation estimates for other months are based on this value and the number of days per month.
3. Estimated Buffalo population = 320,000.

<u>Source</u>: Written communication from S.A. Buczkowski, Buffalo Commissioner of Street Sanitation. Data for total waste and bulky waste are from 1987. January & February bulky waste data from 1987 were not available, so 1988 data were used. March and April bulky waste was estimated from actual data for other months.

recycling to Buffalo's trash disposal problem, it is useful initially to compare the two approaches.

A. Partial Recycling:

This is the conventional approach. It is targeted on the recovery of a few specific components of household or commercial waste: newspapers, cardboard, office paper, aluminum cans or glass bottles. Typically, such programs have been (1) voluntary, leading to low rates of participation; (2) economically precarious because they have not included the avoided cost of landfilling in their accounting; and (3) troubled by difficulty in marketing their products because they are not processed after collection and are therefore low in quality. Of the separate partial recycling programs, only recovery of aluminum cans can be regarded as somewhat successful. Nationally, about 50% of the annual production is collected and reused by the aluminum industry (The Aluminum Assn., 1987). In contrast, only 21% of discarded paper and 7% of discarded glass products are now recycled. According to a recent survey (Pettit, 1986), those communities with recycling programs recover an average of only 7% of the total trash stream. Accordingly, such partial recycling programs cannot be regarded as a means of dealing with the trash disposal problem as a whole.

B. Intensive Recycling:

This approach is intended to deal, not with separate recyclable components, but with the trash stream as a whole -- that is, it is meant to be a self-sufficient means of trash disposal. Unlike partial recycling, intensive recycling is therefore an alternative to incineration. At the request of the Town of East Hampton, CBNS devised such a system in 1986 (see

Commoner *et al.*, 1986). The system begins in the household, where trash is separated into four containers: food garbage and other putrescible material; paper and cardboard; metal cans and glass bottles; non-recyclables (largely plastic). Then, several intermediate processing facilities convert the recyclable components into marketable commodities. Food garbage (together with yard waste) is converted into compost, a useful soil additive; the paper/cardboard fraction is separated into several grades of marketable commodities; the bottle/can fraction is processed to yield marketable aluminum and tin cans and crushed glass. This intensive recycling system is illustrated in Figure 1. The present study is designed to assess the feasibility of applying it to the disposal of Buffalo's household and commercial trash.

C. The Requirements for Intensive Recycling:

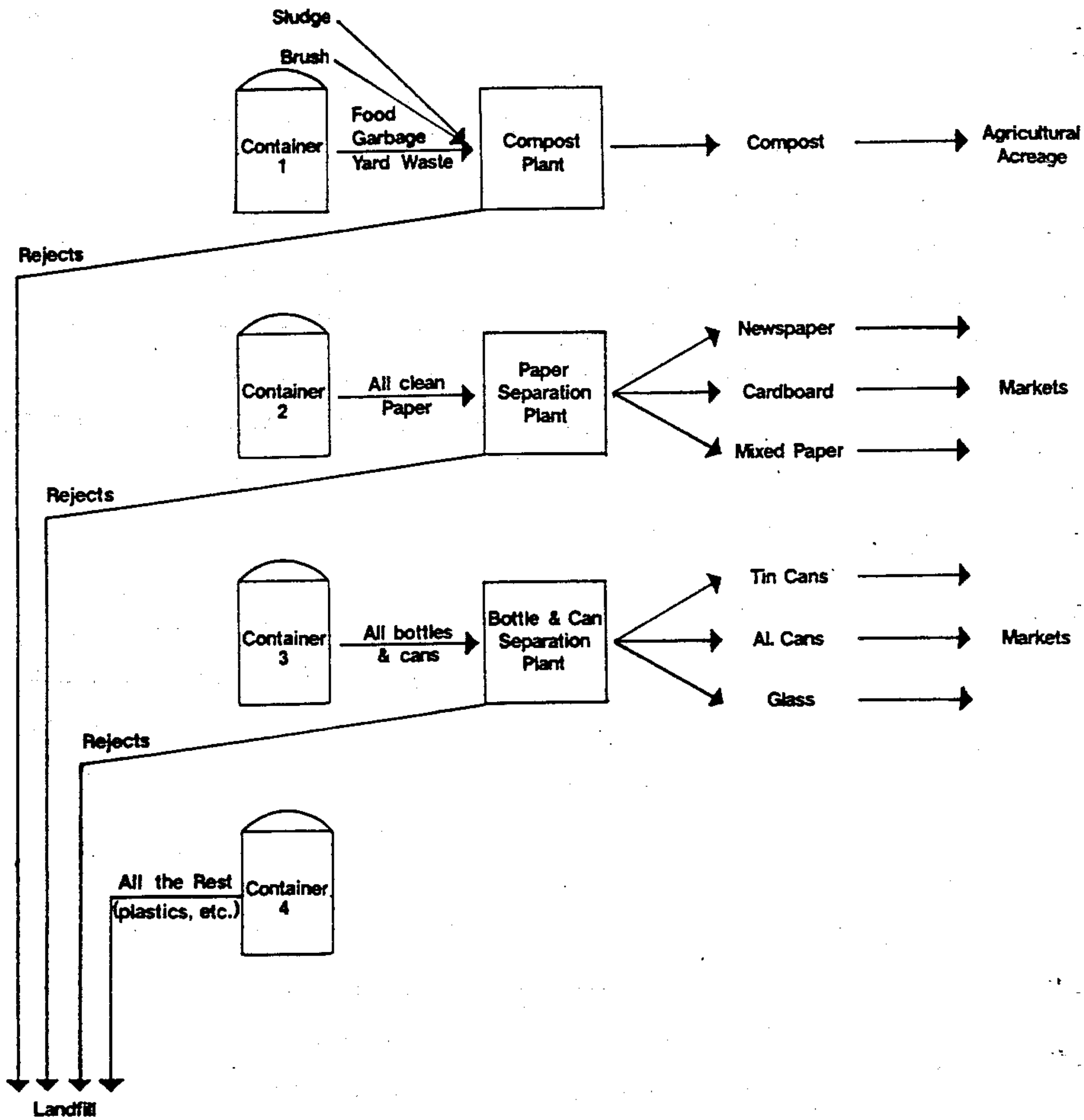
In order to serve its purpose as a complete system of trash disposal, an intensive recycling system must meet the following requirements:

1) It must have a high level of household participation, since, along with the physical efficiency of the system, this determines how much of the trash stream is actually recycled. In order to achieve a high rate of participation, household separation procedures should be convenient and readily understood.

2) Collection procedures should be compatible with the organization, personnel and equipment of the City Department of Street Sanitation.

3) The processing facilities that are required to convert

FIGURE 1
BASIC SEPARATION SCHEME



the household separated materials to marketable products should be based on equipment and procedures of proven capability.

4) The final products of the system must be of a quality acceptable to users (i.e., they should be marketable) and the demand for the products must be ongoing, so that these materials do not accumulate unduly.

5) It must have a high level of physical efficiency -- that is, recover in usable and/or marketable form as much as possible of the residential trash stream. The theoretical maximum recovery is about 85%; the practical minimum is about 70%, which is the amount of the trash stream by weight that is disposed of by the alternative to intensive recycling -- incineration.

6) The non-recyclable residue of the system should be kept to a minimum and should be acceptable for disposal in an ordinary landfill.

7) The system's environmental impact should be equal to or less than the impact of the present system of disposal.

8) The system should be cost-effective and its total net cost should be competitive with the anticipated cost of the City's present system of trash disposal.

The requirements summarized above translate into technical requirements that are explained in Appendix D.

In order to assess the feasibility of employing a system of intensive recycling for trash disposal in Buffalo, we have investigated how these requirements can be met as fully as possible under local conditions. These investigations and their results are described in the following section.

III. DEVELOPMENT OF THE BUFFALO INTENSIVE RECYCLING SYSTEM

A. Household Separation:

Household separation is the essential first step in intensive recycling: unless the trash components are properly separated, it is difficult to process them into high quality, marketable products; unless separation is efficient, the unrecycled residue may be so large as to demand too much landfill space. In addition, the pattern of separation must be compatible with the requirements of the subsequent processing. As noted below, effective mechanical facilities are available that process food garbage and yard waste into compost; mixed paper and cardboard into separate marketable products; and mixed metal cans and glass bottles into a series of marketable metal and glass products*. Hence, household separation should yield these three fractions of recyclable components, and a fourth group of non-recyclables. In order to yield products of acceptable quality, all three recyclable fractions must be kept free of toxic materials (e.g., batteries, pesticides) and the paper/cardboard and can/bottle fractions must be free of food garbage. The household containers for the separate components should be convenient with respect to size and shape. Finally, the overall system should not be unduly demanding of the householder, so that a high level of participation can be attained.

1. Household separation scheme:

A four-container separation scheme has been devised and

*It is possible to combine the paper/cardboard and bottle/can fractions in a single container and then separate and process them at a facility. However, the two leading processing systems designed in the United States (Resource Recovery Systems and NECR Inc.) process them separately.

tested in East Hampton, Long Island. Household trash is separated as follows:

Container I: Food garbage and other putrescible material together with discarded tissue, food-soiled paper, and yard waste.

Container II: Newspaper and other forms of clean paper and cardboard, including food cartons free of contamination.

Container III: Metal cans, glass bottles and jars, and small pieces of aluminum (such as aluminum foil), rinsed by the householder before disposal.

Container IV: All the rest of the regular trash, including discarded plastic, metal and ceramic kitchenware, textile, small rubber items. Also included in this category are composite packaging materials, such as: paper/wax (milk and juice cartons); paper/plastic; and paper/plastic/foil. These materials are not readily recyclable.

It was found that the main problem involved in initiating this procedure was householders' uncertainty about where some items are supposed to go. People sometimes forget which container number is associated with which type of component. To overcome these difficulties, colored logos were used to indicate the different containers and householders were provided with a check list to guide the separation process. Such a list, which also illustrates the logos, is shown in Figure 2.

2. Household containers:

While the importance of container design in facilitating household participation has been recognized, the available literature has not assessed the four-container intensive recycling system. However, the East Hampton pilot project has generated

FIGURE 2:

WHERE THINGS GO

Food Garbage

EXAMPLES

- food scraps (including bones, shells)
- soiled paper
  - tissue
  - napkins & towels
- tea bags
- coffee filters, grounds
- kitty litter
- hair
- tampons (minus plastic applicators)
- sanitary napkins
- fireplace ash (from untreated branches/logs)
- yard waste (small amount)

Clean Paper

EXAMPLES

- newspapers
- magazines
- writing paper
- discarded mail
- advertising fliers
- paper bags
- cardboard boxes
- paper packaging

Metal Cans Glass Bottles

EXAMPLES

- food and juice cans
- coffee cans
- pet food cans
- glass juice bottles
- wine bottles
- liquor bottles
- glass food jars
- aluminum foil
- aluminum food trays

Nonrecyclable (all the rest)

EXAMPLES

- all plastic or mostly plastic items
- plastic food container (eggs, yogurt)
- plastic bottles (non-deposit)
  - gallon milk jugs
  - Chlorox
  - salad oil
  - shampoo
  - medicines
- composite containers (paper + foil, wax, plastic)
  - milk and cream
  - orange juice
  - Brick-pack juice
- plastic film wrap
- plastic food trays (eg. meat)
- aerosol spray cans (eg. shaving cream)
- small scrap metal
- worn clothes, shoes
- dust sweepings
- broken glass
- light bulbs
- leather, rubber
- disposable diapers
- plastic packaging
  - polyurethane foam
  - "blister packs"
- broken plastic toys
- collapsible tubes (eg. toothpaste)
- ceramics
- cigarette ash/butts

NOTES:

- Please rinse food residue from cans, bottles, foil and film before placing in container.
- It is essential to keep the containers of recyclables "pure" -- that is, as free as possible of <u>non</u>-recyclables. So: WHEN IN DOUBT, PUT IT IN THE NON-RECYCLABLES.

FIGURE 2: **WHERE THINGS GO**

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considerable information and experience on this issue (see Appendix B). Based on this information and discussions with householders in Buffalo, the following containers are recommended for the City's intensive recycling system.

- <u>Container I</u> (food and soiled paper): Brown paper bags, such as those used in supermarkets. These are to be used as liners inside a plastic bucket with a lid. When full, the bags are transferred to an outside, closed trash can for collection. (Paper bags rather than plastic ones should be used to line this container, because paper is compostable while plastic is not.)

- <u>Container II</u> (clean paper): All items are collected in a large (11 gallon) plastic box; alternatively, mixed paper is collected in paper bags and newspapers are tied into bundles. The box and/or bags and newspaper bundles are set out at the curb in time for the weekly collection.

- <u>Container III</u> (bottles and cans): These are placed in a six-gallon plastic bucket, which is set out at the curb in time for the weekly collection.

- <u>Container IV</u> (non-recyclables): These items are placed in a conventional plastic trash bag that lines an existing kitchen trash can. When full, the bag is tied and set out at the curb in time for the weekly collection.

Thus, in addition to the conventional kitchen trash can and plastic liner, the household will use three plastic containers (two buckets, one box), and paper grocery bags. (Local stores should be encouraged to use paper bags rather than plastic bags.) The buckets and box should be supplied to householders at the start of the intensive recycling program as part of a free "recycling kit."

3. Outside containers:

The types of containers appropriate for curbside collection depends on several considerations: the need to enclose food garbage in a rigid container at curbside; ease of handling by sanitation workers; security from animals.

According to a local ordinance, food garbage must be enclosed in a rigid outside container when it is left at the curb for collection. Since collection is weekly, the container should be large enough to hold the food garbage produced in that period of time.

The requirements for outside containers to hold paper/ cardboard, bottles/cans, and non-recyclables are less stringent. Since they should not contain putrescible material, they need not be tightly enclosed or protected from animals. Accordingly, the simplest arrangement is to bring the containers used in the kitchen for paper/cardboard and bottles/cans and the plastic bag used to line the container of non-recyclables to the curb for collection. Their contents can be readily distinguished by the sanitation workers, since the paper/cardboard and bottle/can fractions will be in differently shaped containers and the non-recyclables in plastic bags.

4. Level of participation:

Although this crucial question can only be answered in practice, we have investigated one factor that is often believed to have a major effect on people's willingness to participate in household separation of trash: socio-economic differences among

FIGURE 3

CITIZEN ACTION/CBNS BUFFALO HOUSEHOLD RECYCLING TELEPHONE SURVEY

Interview Form

Introduction:

Hello. Is the head of the household home?

My name is ___. I'm calling on behalf of Citizen Action Buffalo. We've been asked by the Buffalo Common Council to take a close look at a new way to deal with our city's garbage. At present our garbage is burned in a Niagara Falls incinerator, but that creates pollution problems and will probably mean higher costs for the city. Right now we're doing a survey to get peoples' feelings about a new garbage system -- recycling -- that could solve these problems and at the same time create new industries and jobs in Buffalo.

Do you have a few minutes to answer some questions? (If they say no, try to schedule a more convenient time to call back and do the interview. If they refuse to participate, move on to the next interview.)

Right now you put all your garbage and trash into a single plastic bag or container for collection by the city. In order for a recycling system to work, each household would have to separate the trash into several different bags or containers -- for example, one container only for food garbage; another for paper and boxes; a third for cans and bottles.

1. Do you think that most people in your neighborhood would be willing to separate their trash in this way?

__ Yes
__ No
__ Don't know

neighborhoods. Such differences might be expected, for example, to influence public attitudes toward recycling or physical constraints on separation (for example, due to differing sizes of kitchens). A survey by EPA (U.S. EPA, 1979) made an attempt to evaluate socio-economic factors (including average income and level of education) on participation rate, but the results are confused by disparate sources of data and, in any case, are characterized as "not a strong relationship."

In order to determine the attitude of the general population toward household separation as well as the relative degree of participation that might be expected from neighborhoods that differ in their socio-economic characteristics, a household telephone survey on the subject of trash management and recycling was conducted in three Buffalo neighborhoods. The survey was designed by CBNS and Citizen Action-Buffalo and carried out by the latter organization. The three communities represented a total of 47,585 residents. Masten is a predominantly black neighborhood, Fillmore is predominantly white and ethnic, and Delaware is described as primarily upwardly mobile and professional.

A random sample of households was telephoned in each community between the hours of 5:00 PM and 9:00 PM during December 1987. All 514 respondents were given the same brief introduction describing the trash problem and what a household separation procedure would entail. The seven questions listed in the interview form were then asked. They allowed for several options as responses. The questionnaire is shown in Fig. 3 and the results are presented in Table II.

2. Would *you* be willing to separate your trash in this way?

__ Yes
__ No
__ Don't know

3. [If the answer to (2) is "no" or "don't know"]:

You say that you are unwilling (or don't know if you are) to separate the trash. Here are some reasons why some people might feel this way. Which of these are your reasons?

__ Too little space in kitchen
__ Would take too much time
__ Other people in the household (children) wouldn't cooperate
__ Other

4. Which of these arrangements do you think would help to encourage people to separate their trash?

__ A City law that requires separation
__ A cash prize given weekly for well-separated trash
__ The City would refuse to pick up unseparated trash
__ The City would provide you with free trash bags
__ Other ideas ____________________

5. What do you think of the way in which the City now collects the garbage?

__ Satisfactory
__ Not satisfactory
__ Don't know

6. What should be done to improve the present system? ____________________

7. We would like to have the following information:

How many apartments are there in your building? __________
How many people live in your apartment? __________
How many of them are children? __________

Table II

CITIZEN ACTION/CBNS HOUSEHOLD RECYCLING TELEPHONE SURVEY OF BUFFALO, 12/87

		Delaware Area (HOUSEHOLDS: 15,224)		Fillmore Area (HOUSEHOLDS: 15,743)		Masten Area (HOUSEHOLDS: 16,618)		TOTAL	PERCENT
Number of Respondents:		162		165		187		514	
1) Do you think that your neighbors would separate their trash?	yes	45	27.8%	30	18.2%	59	31.6%	134	26.2%
	no	48	29.6%	55	33.3%	54	28.9%	157	30.5%
	don't know	68	42.0%	79	47.9%	74	39.6%	221	43.0%
	no response	1	0.6%	1	0.6%	0	0.0%	2	0.4%
2) Would you be willing to separate your trash?	yes	131	80.9%	122	73.9%	148	79.1%	401	78.0%
	no	26	16.0%	29	17.6%	27	14.4%	82	16.0%
	don't know	4	2.5%	14	8.5%	11	5.9%	29	5.7%
	no response	1	0.6%	0	0.0%	1	0.5%	2	0.4%
3) If not yes, what is your reason?	inadequate space	13		15		13		41	
	insufficient time	7		15		17		39	
	uncooperative people	1		5		4		10	
	other	8		6		5		19	
4) What would help encourage people to separate? *	city law	88	30.2%	63	23.2%	56	20.5%	207	28.1%
	cash prize	34	11.7%	43	15.8%	58	21.2%	135	18.4%
	pick up refused	64	22.0%	43	15.8%	37	13.6%	144	19.6%
	free trash bags	57	19.6%	77	28.3%	92	33.7%	226	30.8%
	other	40	13.7%	37	13.6%	28	10.3%	105	14.3%
	no response	8	2.7%	9	3.3%	2	0.7%	19	2.6%
5) Your opinion of city trash collection?	satisfactory	123	75.9%	130	78.8%	137	73.3%	390	75.9%
	not satisfactory	24	14.8%	29	17.6%	40	21.4%	93	18.2%
	don't know	11	6.8%	4	2.4%	6	3.2%	21	4.1%
	no response	4	2.5%	2	1.2%	4	2.1%	10	2.0%
6) What should be done to improve present system?	# of responses	67	41.4%	69	41.8%	87	46.5%	223	43.4%
7a) Number of units in building?	single unit	70	43.2%	76	46.1%	74	39.6%	220	42.8%
	2 to 4 units	60	37.0%	86	52.1%	107	57.2%	253	49.2%
	5 to 50 units	18	11.1%	0	0.0%	6	3.2%	24	4.7%
	51 to 99 units	6	3.7%	0	0.0%	0	0.0%	6	1.2%
	100 or more	8	4.9%	3	1.8%	0	0.0%	11	2.2%
7b) Composition of household?	one occupant	54	33.3%	40	24.2%	47	25.1%	141	27.4%
	two occupants	62	38.3%	46	27.9%	50	26.7%	158	30.7%
	3 or more	31	19.1%	77	46.7%	90	48.1%	198	38.5%
	no response	15	9.3%	2	1.2%	0	0.0%	17	3.3%
7c) Number of children in household?	no children	122	75.3%	108	65.5%	120	64.2%	350	68.1%
	1 child	13	8.0%	25	15.2%	20	10.7%	58	11.3%
	two children	18	11.1%	15	9.1%	31	16.6%	64	12.5%
	more than two	9	5.6%	17	10.3%	16	8.6%	42	8.2%

* Respondents may have chosen more than one option from question #4. Therefore, total resposnes are greater than the number of respondents. Percentages indicate the frequency of a given option selected by respondents.

When asked the question, "Do you think that most people in your neighborhood would be willing to separate their trash in this way (referring to the use of four containers)?", an average of only 26% of the total said "yes." However, asked "would you be willing to separate your trash in this way?", an average of 78% of the respondents said "yes." The difference between these two responses is not surprising. Since recycling has not been widely discussed, individual respondents had no way of knowing that most of their neighbors would respond favorably. The other 22% of the respondents who said "no" or "don't know" gave reasons that included inadequate space, insufficient time, and the presence of people in the household who wouldn't cooperate (such as children).

The answers to questions on how people could be encouraged to cooperate with a household separation program varied. The option that elicited the greatest number of favorable responses (30.8%) was the idea of offering free trash bags. Another frequent response (28%), was the notion of a law requiring recycling. Some respondents suggested that the media should be used comprehensively to educate the public about the benefits of recycling. Some suggested tax breaks for recyclers and incentives similar to the bottle bill.

As shown in Table II, the differences in the responses obtained from respondents in the three neighborhoods are small. In response to the crucial question, "Would you be willing to separate your trash?", the percentages answering "yes" were 80.9% in Delaware, 73.9% in Fillmore, and 79.1% in Masten. These differences are not statistically significant. Compared with data of the U.S. Census Bureau, the surveyed population reflected an accurate composite of the Buffalo area. The number of units per building, the number of occupants per household, and the number of children per household are consistent with census figures.

In addition to the telephone survey of the three neighborhoods, a face-to-face survey was conducted for one of them (Masten), for comparison with the results of the telephone survey. This comparison can correct for a possible difference in the responses from households with and without telephones. A standard statistical (Chi square) test indicates that there is no statistically significant difference between the two surveys at a 95% confidence level. The comparative results are shown in Table IIa.

Since these neighborhoods are representative of the city as a whole, the survey indicates that it should be possible to obtain a high level of participation in a full-scale trash separation program in Buffalo. Even without an education program, the study indicates that nearly 80% of the population is ready to participate. This positive initial attitude toward recycling will, of course, need to be fortified with education and incentives. Although no consistent or uniform measures of the effectiveness of recycling education are available, the existing literature on source separation programs consistently emphasizes the importance of vigorous, continuing public education campaigns to encourage participation. Such an educational program is described in Section VII.

B. <u>Collection System</u>:

At present the City's trash collection system picks up

Table IIa

COMPARISON OF TELEPHONE SURVEY RESULTS AND FACE-TO-FACE SURVEY RESULTS FOR MASTEN

		Telephone Survey Masten Area (HOUSEHOLDS:16,618)		Face-to-face Survey Masten Area (HOUSEHOLDS: 16,618)		Chi Square Statistical Comparison**			
Number of Respondents:		187		169		Expected	O - E	(O-E)sq/E	Sum = Xsq
1) Do you think that your neighbors would separate their trash?	yes	59	31.6%	48	28.4%	53.3	5.7	0.60	2.09
	no	54	28.9%	32	18.9%	48.8	5.2	0.55	
	don't know	74	39.6%	87	51.5%	66.9	7.1	0.76	
	no response	0	0.0	2	1.2%	0.2	-0.2	0.17	
2) Would you be willing to separate your trash?	yes	148	79.1%	123	72.8%	133.8	14.2	1.52	1.92
	no	27	14.4%	38	22.5%	24.4	2.6	0.28	
	don't know	11	5.9%	7	4.1%	9.9	1.1	0.11	
	no response	1	0.5%	1	0.6%	0.9	0.1	0.01	
3) If not yes, what is your reason?	inadequate space	13		5	3.0%				
	insufficient time	17		16	9.5%				
	uncooperative people	4		10	5.9%				
	other	5		11	6.5%				
4) What would help encourage people to separate? *	city law	56	20.5%	65	22.7%				
	cash prize	58	21.2%	52	18.2%				
	pick up refused	37	13.6%	31	10.8%				
	free trash bags	92	33.7%	104	36.4%				
	other	28	10.3%	30	10.5%				
	no response	2	0.7%	4	1.4%				
5) Your opinion of city trash collection?	satisfactory	137	73.3%	109	64.5%	123.8	13.2	1.40	1.92
	not satisfactory	40	21.4%	49	29.0%	36.1	3.9	0.41	
	don't know	6	3.2%	6	3.6%	5.4	0.6	0.06	
	no response	4	2.1%	5	3.0%	3.6	0.4	0.04	
6) What should be done to improve present system?	# of responses	87	46.5%	82	48.5%				
7a) Number of units in building?	single unit	74	39.6%	58	34.3%	66.9	7.1	0.76	1.92
	2 to 4 units	107	57.2%	105	62.1%	96.7	10.3	1.10	
	5 to 50 units	6	3.2%	2	1.2%	5.4	0.6	0.06	
	51 to 99 units	0	0.0%	0	0.0%	0.0	0.0		
	100 or more	0	0.0%	0	0.0%	0.0	0.0		
7b) Composition of household?	one occupant	47	25.1%	32	18.9%	42.5	4.5	0.48	1.92
	two occupants	50	26.7%	49	29.0%	45.2	4.8	0.51	
	3 or more	90	48.1%	86	50.9%	81.3	8.7	0.92	
	no response	0	0.0%	2	1.2%	0.0	0.0		
	Total Occupants	517		464					
	Average Occupants per Household	2.76		2.78					
7c) Number of children in household?	no children	120	64.2%	87	51.5%	108.4	11.6	1.23	1.92
	1 child	20	10.7%	38	22.5%	18.1	1.9	0.21	
	two children	31	16.6%	25	14.8%	28.0	3.0	0.32	
	more than two	16	8.6%	19	11.2%	14.5	1.5	0.16	

* Respondents may have chosen more than one option from question #4. Therefore, total responses are greater than the number of respondents. Percentages indicate the frequency of a given option selected by respondents.
**This standard procedure, which produces low values of X squared (small difference between observed and expected variables), shows a high probability that the distributions are the same between the face-to-face and telephone

containers of mixed trash at the curb and disposes of their contents, with no further treatment, at the transfer stations. Intensive recycling necessarily requires major changes in the present collection system. First, the new system must be designed to pick up, separately, four different fractions of the waste stream. Second, instead of the trash being delivered to a single transfer station, the different fractions must be delivered to one of several different facilities, where they are processed into marketable products. In this section we consider the design and operation of a collection system capable of carrying out these functions.

1. <u>Types of collection vehicles available:</u>

The types of trucks used to collect trash containers have major effects on collection time, route lengths, and working conditions. The trucks represent a major part of the system cost, so that an effort should be made to use existing Sanitation Department trucks insofar as possible. The following types of trucks are now in use or are available through purchase.

a. <u>Compactor trucks</u>:

Urban residential collection of unsorted solid waste is performed almost exclusively with compactor trucks. These trucks are loaded either manually or by a hydraulic bin lift system. In Buffalo, residential collection is performed with manually loaded compactor trucks. Such compactor trucks can be used to collect separated trash fractions, providing that compaction does not interfere with subsequent processing. They are available in a range of sizes.

b. Non-compaction trucks:

Trucks that do not compact the trash and have one or more separate compartments for receiving different waste fractions have been introduced for the collection of household-separated trash. Some of these trucks are loaded with a hydraulic mechanism that can access all compartments. Since the trash is not compacted, such trucks have a relatively small capacity; they are available in a range of sizes.

c. Trailers:

Both non-compaction and compaction trailers are available, but the supply of the latter is limited. Compactor trailers with a payload of more than about 5000 lbs are rarely offered. Non-compaction trailers range from small single-compartment vehicles to 15 cubic yard trailers with several compartments.

All trailers need a source of hydraulic power for brakes, the dump mechanism, and, in the case of compactor trailers, the compaction mechanism. Hydraulic power is provided either by a line from the truck that pulls the trailer or by a separate engine on the trailer itself. In the first case, the power supply of the truck must be matched to the requirements of the trailer. In addition, the hitch on the truck and the trailer's tongue should match. If a trailer is to be pulled by a rear-loading compactor truck, special arrangements may be needed to match the truck hitch and trailer tongue and to avoid impeding the loading of the truck. Some rearloading trucks cannot pull a trailer at all, while others can only pull a relatively small load.

Collection vehicles should require a minimum effort for loading and should be suitably maneuverable. Vehicle handling performance in dense traffic, in narrow alleys, after heavy snowfall, steep hills, or when backing out of dead end streets should be considered.

2. Vehicle design considerations:

The choice of the best truck-trailer combination is affected by the following considerations: collection frequencies and schedules; relative sizes of each of the four waste fractions; which of the separated fractions may be compacted without interfering with subsequent processing; the extent to which Buffalo's existing 25 cubic yard compactor trucks could be used in the intensive recycling system; maneuverability of truck-trailer combinations.

a. Collection frequencies and schedules:

Available evidence suggests that household participation in recycling programs is enhanced if pickups always occur on the same day of the week. According to a survey done by the National Solid Waste Management Association (NSWMA), the average rate of participation in recycling among 13 communities with recycling ordinances was 76.5% with "same day" pickups and 41% without (Pettit, 1986). In contrast, according to the survey, the frequency of collection did not significantly affect participation rate. These results suggest that the City of Buffalo should continue with a once-per-week pickup schedule and that in each neighborhood all four fractions should be collected on the same day of the week.

b. Sizes and characteristics of the four trash fractions:

We can estimate the relative amounts of the four fractions of the Buffalo residential waste stream (by weight) from data obtained in the East Hampton test. However, since the East Hampton trash stream had an unusually high newspaper content, we have corrected this figure to bring it closer to the average values reported at materials recovery facilities (McCauley, 1988). From reported data on the density of different trash components (Peavy *et al.*, 1985), it is then possible to estimate the relative amounts of the four separated fractions. Table III summarizes these calculations. (See Appendix A for details.)

In winter months when little or no yard waste is being generated, the paper/cardboard fraction represents the largest volume of material. During the summer, food garbage/yard waste becomes the largest fraction. The bottle/can fraction represents the smallest volume -- about half the volume of the non-recyclables.

c. Truck design:

The optimal truck design is based on the following considerations:

- The food/yard waste, paper/cardboard, and non-recyclable fractions can be compacted; the bottle/can fraction cannot (the resulting breakage interferes with subsequent processing).
- The paper/cardboard and bottle/can fractions will usually be delivered to adjacent processing facilities.
- Total collection mileage should be minimized.
- The truck and trailer capacity must be sized so that: (i) they can accommodate the maximum seasonal waste generation rates; and (ii) the truck and accompanying trailer fill up at about the same rate.

Table III

AMOUNTS OF SOURCE-SEPARATED REGULAR MATERIALS GENERATED
(At 90% Household Participation Rate)

	Cont. I Food	Cont. II Paper/ Cardboard	Cont. III Bottles/ Cans	Cont. IV Non-Recycl.*	Total
Winter (No Yard Waste):					
Weight (tons/day)	109.3	109.1	44.5	77.9	340.8
(Percent of total)	(32.1)	(32.0)	(13.1)	(22.9)	(100)
Density: ton/yd^3	0.169	0.063	0.122	0.055	
Compaction ratio	2	3.5	1	4	
Volume (yd^3/day):					
uncompacted	648	1726	364	1194	3932
(percentage)	(16.5)	(43.9)	(9.3)	(30.4)	(100)
compacted	324	493	364	354	1535
(percentage)	(21.1)	(32.1)	(23.7)	(23.0)	(100)
Summer Peak (With Yard Waste)					
Weight (tons/day)	238.8	109.1	44.5	92.3	484.7
(Percent of total)	(49.3)	(22.5)	(9.2)	(19.0)	(100)
Density: ton/yd^3	0.129	0.063	0.122	0.055	
Compaction ratio	2.5	3.5	1	4	
Volume (yd^3/day):					
uncompacted	1858	1726	364	1328	5276
(percentage)	(35.2)	(32.7)	(6.9)	(25.2)	(100)
compacted	743	493	364	400	2001
(percentage)	(37.1)	(24.6)	(18.2)	(20.0)	(100)

Notes:
1. Unseparated trash collected from non-participants is included in the non-recyclable fraction.
2. The ratio of uncompacted volume to compacted volume is equal to the compaction ratio.

*The computation of the density and compaction ratio of the non-recyclable fraction assumes that it is not contaminated by unseparated trash -- i.e., that the household participation rate is 100%.

Based on these considerations, we have reached the following design decisions:

- The paper/cardboard and bottle/can fractions should be collected by a compactor truck/non-compactor trailer unit.
- The food/yard waste and non-recyclable fractions should be collected by a compactor truck/compactor trailer combination.

In order to compute the required truck and trailer capacities, the following factors must be taken into account: the expected relative volumes of the four trash fractions; their assumed compaction ratios; and the degree of participation in household separation. The last factor will influence the amount of trash that is set out at the curbside without separation (that is, by non-participating households), and which must therefore become part of the non-recyclable fraction. The computation of required truck and trailer capacities is described in Table IV. (See also Appendix C.)

In this table, the volumes of the three recyclable fractions are assumed to decrease -- and the volume of the non-recyclable fraction to increase -- in proporation to the degree of non-participation. In order to incorporate a safety factor in the vehicle capacities, we used a 100% participation rate for calculating the volumes of recyclables and an 80% participation rate for calculating non-recyclable volumes. On this basis, the capacity requirements can be met by the following equipment:

Unit 1: 20 cu yd side-loading compactor truck (food/yard waste)
14 cu yd side-loading compactor trailer (non-recyclables)

Unit 2: 14 cu yd side-loading compactor truck (paper/cardboard)
10.5 cu yd non-compactor trailer (bottles/cans)

Table IV

REQUIRED CAPACITY OF TRUCKS AND TRAILERS

Household Participation Rate	Minimum Weight (tons)				Minimum Volume (yd³)			
	Food	Paper	Bottle/ Can	Non-Recycl.	Food	Paper	Bottle/ Can	Non-Recycl.
100%	6.6	3.0	1.2	1.2	20.6	13.7	10.1	5.6
90%	6.0	2.7	1.1	2.3	18.6	12.3	9.1	10.0
80%	5.3	2.4	1.0	3.4	16.5	11.0	8.1	14.4

Assume:
- 28 vehicles of each type;
- summer peak volumes;
- collect twice a day, five days per week.

Unit 1 will require the purchase of both new compactor trucks and compactor trailers, since the latter could be hitched to the City's existing compactor trucks only with a good deal of difficulty and additional cost. Unit 2 can be made up by hitching newly purchased non-compactor trailers to existing City trucks. However, the capacity of the present trucks (25 cu yd) is unnecessarily large for the new system. The existing trucks should therefore be gradually replaced by the smaller, less expensive ones. The time of replacement can be determined from the resale value of the present trucks and the cost of purchasing the new smaller ones.

C. Processing Facilities:

Processing of the three fractions of recyclable trash components is essential. In the case of the food garbage/yard waste fraction, processing converts this putrescible and inherently undesirable material into a useful soil-like material: compost. The mixed paper fraction can sometimes be marketed directly, but at a much lower price than can be obtained by marketing separated constituents, such as newsprint. Depending on the prices of grades of separated paper and separation costs, it may be advantageous to process this fraction into several more readily marketed products (the degree of separation should be flexible). The bottle/can fraction must be processed into separate aluminum cans, foil and scrap; tin cans; clear (flint) glass, amber glass and green glass, for most markets will only accept the material in these forms. Mixed glass cullet can be made into certain products, such as fiberglass and "glassphalt" paving material, but these markets are relatively unreliable. In

describe existing, readily available facilities
rt the three fractions of recyclable materials
ehold separation into marketable products.
posting:

municipal wastes has been a common waste
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E.G., 1980). A major portion of the municipal
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1985; Vieten, 1983). In the composting
organic matter is acted on by aerobic
The process quickly eliminates the typical
ually changes the composition of the starting
product is a stable (i.e., not subject to
umus-like material. Since compost is a
it can be viewed as a way of recycling plant
er, which in a fundamental sense is derived

process occurs in two overlapping phases.
oxygen is needed to support the microbial
which lasts about 10-14 days, the system
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the first few weeks of the process,
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. The elevated temperature tends to
organisms that may be introduced if
paring it.

this section we describe existing, readily available facilities that could convert the three fractions of recyclable materials generated by household separation into marketable products.

1. Composting:

Composting of municipal wastes has been a common waste management practice since the 1920's in European and other countries (Hughes, E.G., 1980). A major portion of the municipal solid waste is presently composted in the Netherlands and Austria (Thome-Kozmiensky, 1985; Vieten, 1983). In the composting process, putrescible organic matter is acted on by aerobic bacteria and molds. The process quickly eliminates the typical garbage odor and gradually changes the composition of the starting material. The final product is a stable (i.e., not subject to further degradation) humus-like material. Since compost is a useful soil additive, it can be viewed as a way of recycling plant and animal organic matter, which in a fundamental sense is derived from soil.

The aerobic compost process occurs in two overlapping phases. At first a great deal of oxygen is needed to support the microbial process; in this period, which lasts about 10-14 days, the system must be well supplied with air. In the second maturation phase, less aeration is needed; it lasts a minimum of six to nine weeks, but may be longer. During the first few weeks of the process, microbial metabolism generates a good deal of heat and for a time temperatures are above 55°C. The elevated temperature tends to free the compost of disease organisms that may be introduced if sewage sludge is used in preparing it.

All natural materials can be composted. This includes the following components of trash: food garbage; yard waste such as grass clippings and leaves; and paper. Since paper is usually more valuable if converted into recycled products, only soiled paper (e.g., food wrapping, used tissue) should be included in compost. The composition of the compostable fraction of trash will vary with the season; in particular, yard waste will be generated only in the spring, summer and fall months. In order to support the microbial compost process, the starting materials should contain a certain proportion of carbon and nitrogen. This is readily achieved if a mixture of food garbage and yard waste is composted.

If compost is to serve its purpose in an intensive recycling system, it must be readily usable and/or marketable. This depends on its composition, which in turn is determined by the ingredients of the compost mixture. The major deterrent to the use of compost is the presence of toxic materials such as lead, cadmium and mercury (see Appendix D, Table D-I), and toxic chemicals such as pesticides. Federal and state regulations restrict the amounts of such toxic materials that may be present in compost used on acreage on which crops are grown. These restrictions do not apply to non-agricultural uses such as lawns, golf courses, and other horticultural activities. State regulations also restrict the use of compost if sewage sludge is used as one of the ingredients. Compost that contains fragments of non-compostable materials such as plastic, glass or metal is also undesirable and difficult to market.

Since Buffalo is served by a single sewage treatment plant, we assume that its sludge is probably contaminated by heavy metals originating in industrial effluents, and hence not suitable for compost production.

These constraints dictate the separation of food garbage from all other components of the trash stream. Since some contaminants may occur in household-separated food garbage, a screening step is included in the subsequent processing at the compost facility.

Since the proposed intensive recycling system involves household separation of food garbage from the rest of the trash, the resultant compost can be expected to contain acceptable levels of toxic metals. Some toxic chemicals may enter the compost in yard waste that has been treated with pesticides and herbicides, but the extent of this problem will depend a great deal on local conditions and can only be determined in practice. Because the proposed Buffalo system is based on household-separated food garbage, its compost product can be expected to be quite free of extraneous matter such as plastic, glass or metal.

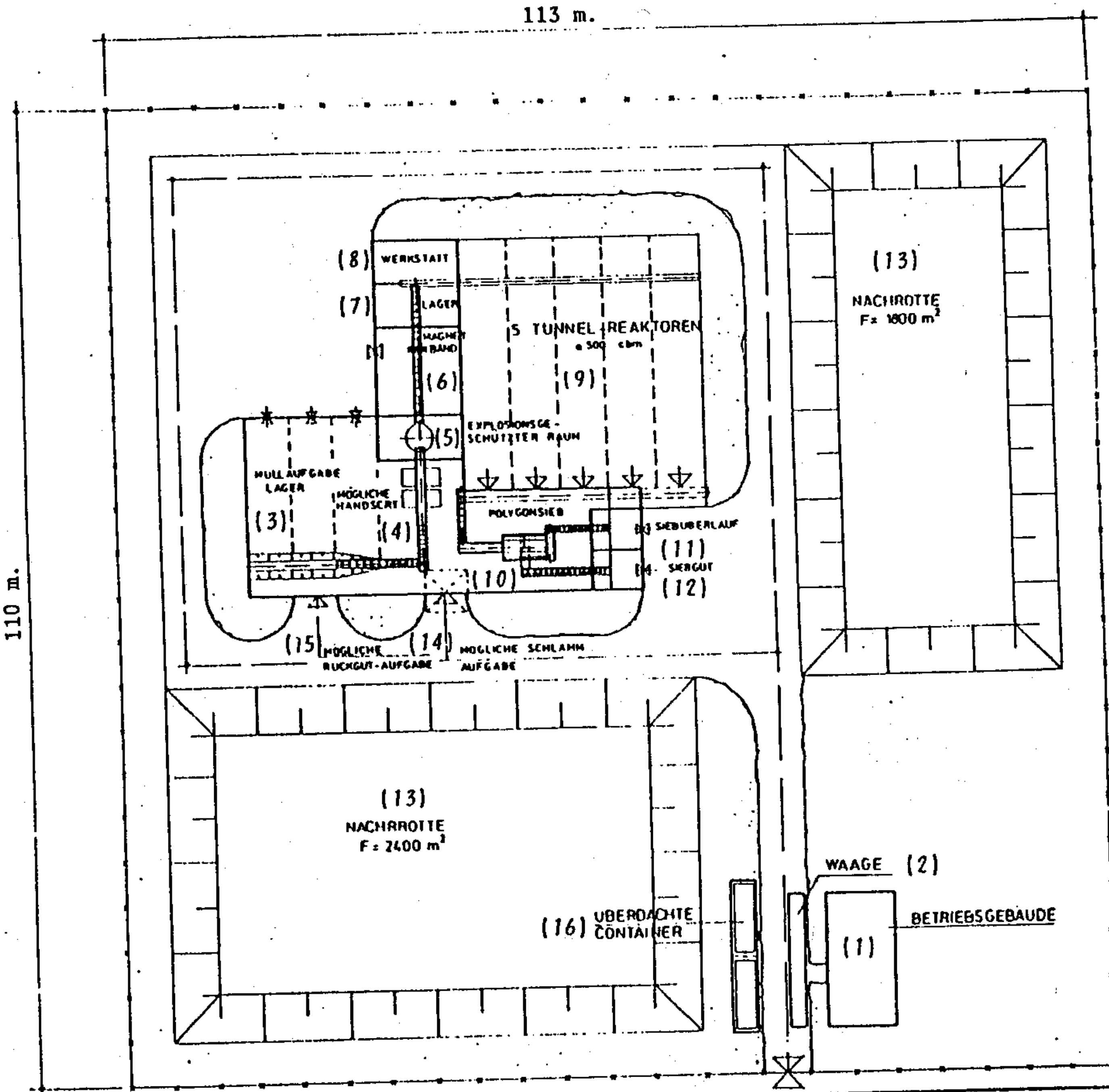
Facilities for compost production vary a great deal in complexity. If the site is sufficiently isolated so that garbage odor problems are not troublesome, compost can be prepared by forming a long mound ("windrow") that is aerated by being turned over periodically by means of an ordinary front-end loader. This may also be accomplished by a specially designed machine. Alternatively, an "in-vessel" system can be used to produce compost. In this case, the compost is enclosed, so that odors can be readily controlled; aeration is generally accomplished by forcing air through the compost. In-vessel systems also require less land area than windrow systems.

In the Buffalo intensive recycling system, the compost facility will probably be located within the city limits. For this reason, and also to protect the process from the city's severe winters, an in-vessel compost system should be used. However, since it will receive household-separated food garbage, the facility should require only minimal equipment to remove extraneous material that may sometimes occur in the food garbage fraction. The design of one such compost facility is shown in Figure 4. A list of vendors of this type of compost facility is provided in Appendix E.

2. Materials recovery facilities (MRFs):

Intermediate processing of recyclable materials is an essential part of any system designed to achieve a high rate of recovery and reuse of materials. The key to successfully marketing recyclable materials is to produce a stable supply of products of a quality that is acceptable for use as a secondary material in manufacturing processes. In the intensive recycling system, the recyclable fractions produced by household separation are not in a marketable form, and they must be processed. The MRF receives the two non-food recyclable fractions -- paper/cardboard and bottles/cans -- and converts them into products that are acceptable to manufacturers of new products, such as glass containers or recycled paper.

The design of a typical MRF suitable to the intensive recycling system is shown in Fig. 5. This plant receives household-separated bottle/can and paper/cardboard fractions. The bottles/cans are directed down a conveyor belt where they are sorted by a combination of hand-picking and mechanical separation



(1) Office
(2) Scale
(3) Waste reception & storage
(4) Hand picking
(5) Explosion-proof room with mill
(6) Magnetic separation
(7) Storage
(8) Repair shop
(9) 5 tunnel reactors
(10) Trommel-sieve
(11) Over-sized
(12) Raw compost
(13) Compost maturation
(14) Possible sludge tank
(15) Possible raw compost feed
(16) Containers

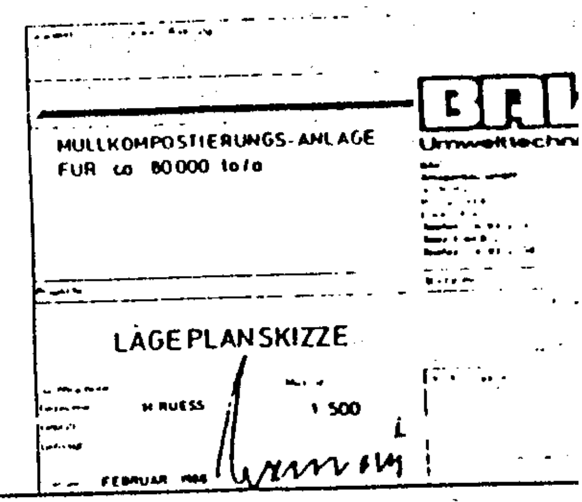


FIGURE 4- Design of Compost Facility

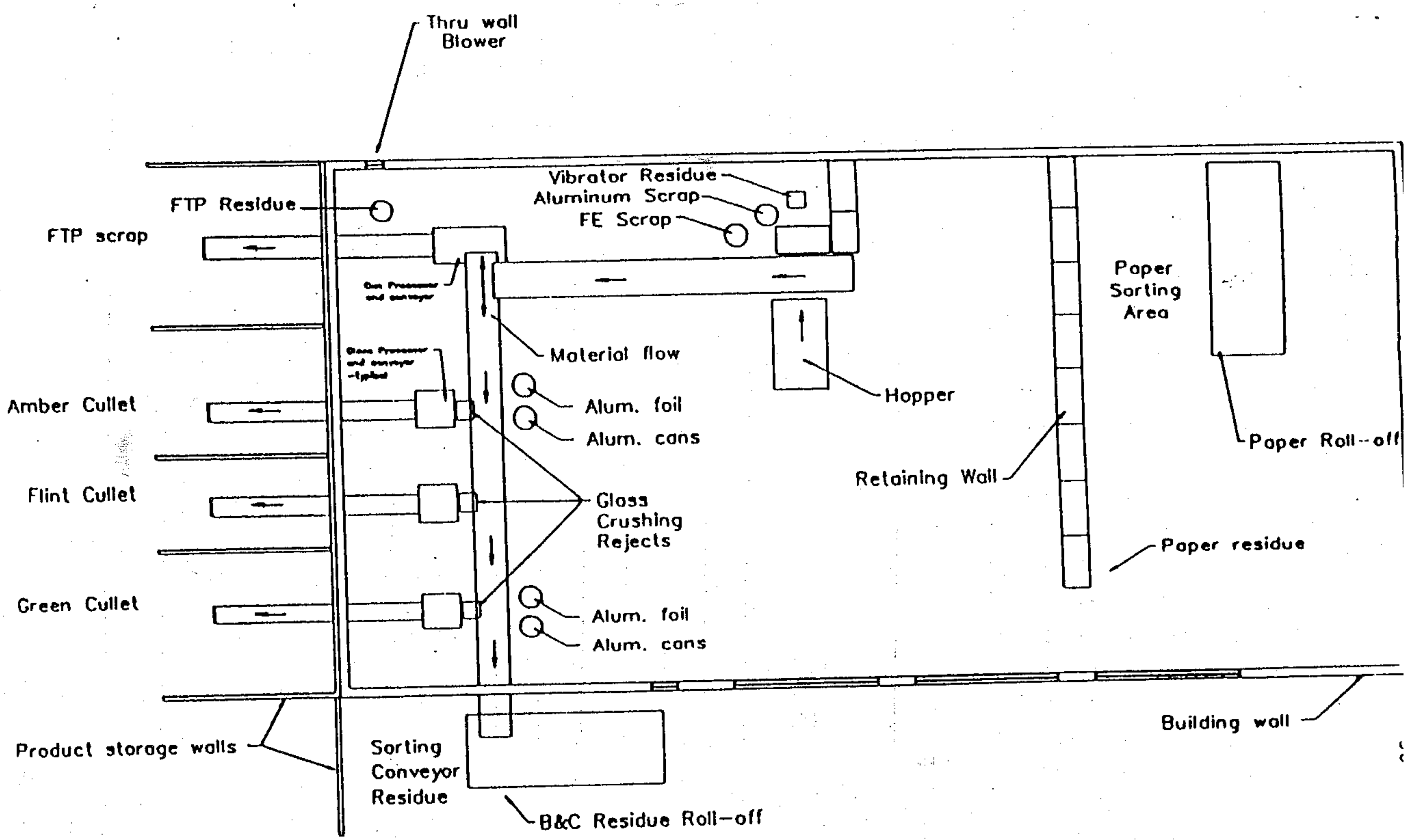


FIGURE 5: Design of Materials Recovery Facility

RRS
Groton Recycling Facility
East Hampton Recyclable Processing Test
Collection points for separated recyclables identifie
Aluminum and glass separated on second level.

into separate streams (tin cans, aluminum cans, other types of aluminum, amber glass, clear glass, green glass). Metal cans are shredded or flattened according to manufacturer specifications. Glass is separated by color and crushed into glass cullet for shipment. Paper and cardboard are hand-sorted into various grades. A list of vendors of MRFs suitable for processing the bottle/can and paper/cardboard fractions produced by the intensive recycling system is presented in Appendix E.

Figure 6 is a diagram of the entire intensive recycling system.

3. The physical efficiency of intensive recycling:

The efficiency with which the recyclable material can be recovered in marketable form depends on the combined effectiveness of household separation and the subsequent processing of the separated components. The East Hampton Pilot Test, conducted over a 10-week period with 100 volunteer households, provides an efficiency figure for household separation of residential waste. Each participating household separated their trash into four containers, according to the scheme outlined earlier. These were weighed as they were delivered to the recycling center. A total of about 18 tons of separated trash was collected

Table V summarizes the results of this test. The contents of Containers I, II and III, which represent potentially recyclable material, accounted for 86.8% (by weight) of the total household trash stream. The contents of Container IV, which represent materials that are not currently recyclable, amounted to 13.2% of the total trash stream. (Yard waste was collected separately, and the amounts are not included in the above figures.)

The materials in Containers II and III have been processed by

Figure 6 THE PROPOSED BUFFALO INTENSIVE RECYCLING SYSTEM

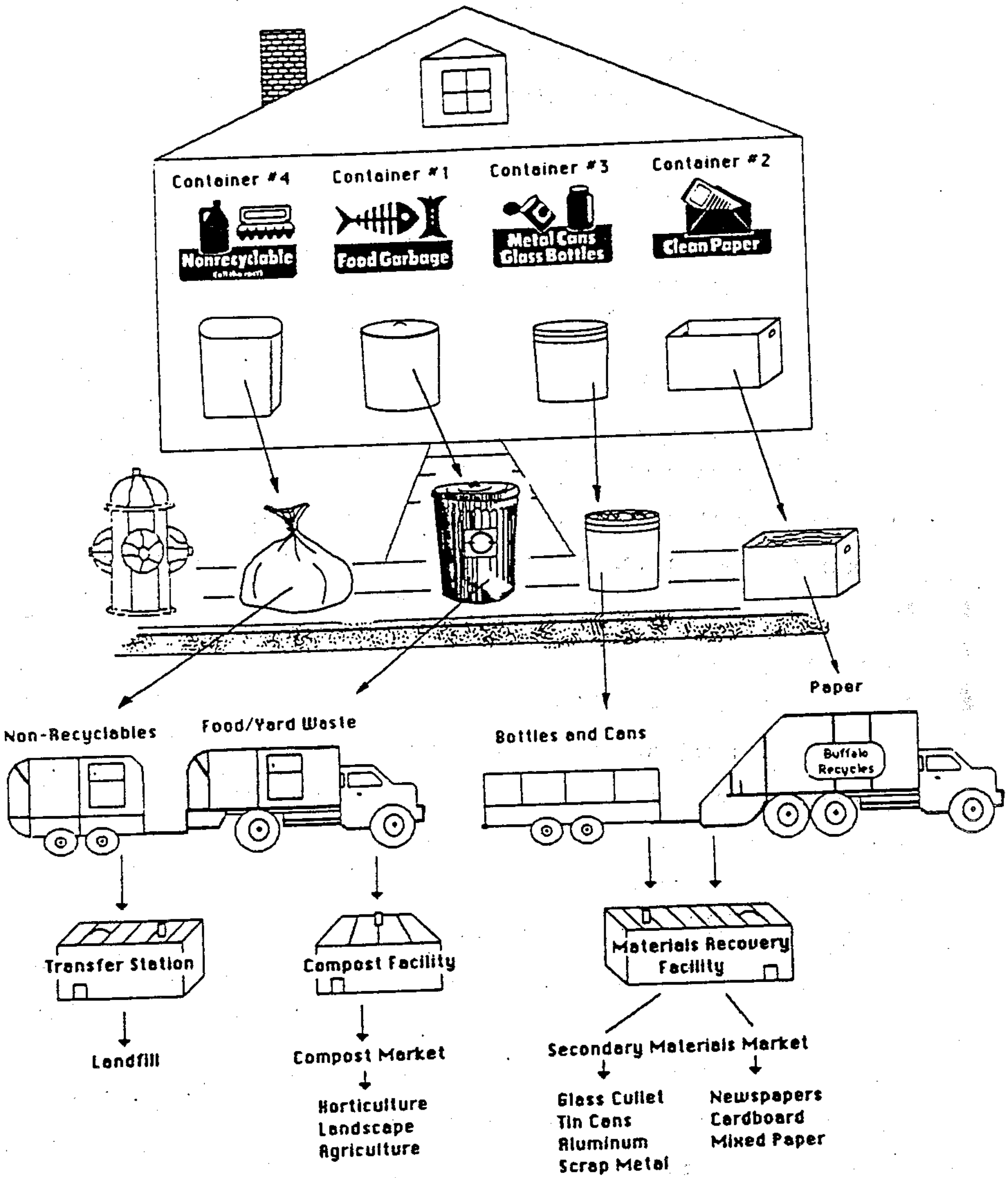


Table V

COMPOSITION OF MATERIAL COLLECTED IN THE EAST HAMPTON PILOT TEST

Container	Weight (lbs)	Percent
I - food/soiled paper	11,900	32.9
II - paper/cardboard	14,633	40.5
III - bottles/cans	4,839	13.4
IV - non-recyclables	4,786	13.2
Total	36,158	100.0

the MRF operated by Resource Recovery Systems, Inc., in Groton, CT. A 9,432 pound sample of the Container II material and all of the Container III material were processed and marketed. The results are summarized in Table VI. Only 0.6% of the Container II material and 9.3% of the Container III material were rejected as not recyclable at the processing plant. Compost produced at East Hampton from the food garbage collected in the test (Container I), together with yard waste and digested cesspool sludge, is still in the final maturation process. However, we estimate that the extraneous material is about 5% of the food garbage input by weight.

The efficiency of the overall process -- that is, household separation plus MRF processing -- is computed in Table VII. These data indicate that only 16% of the total collected household trash was not recyclable. Thus, the physical recycling efficiency for residential waste in the East Hampton pilot test is 84%. This value would be higher if yard waste were included in the computation or if plastics were recycled.

The contents of Container IV (non-recyclable) have been analyzed in detail. As shown in Table VIII, this fraction of the waste stream consists chiefly of plastics, composite containers (i.e., composed of plastic, cardboard, and metallic film), and disposable diapers.

4. <u>The environmental impact of intensive recycling processing facilities</u>:

In connection with the East Hampton Pilot Test, estimates have been made of emissions from the processing facilities that were used in the intensive recycling system, i.e., composting,

Table VI

RESULTS OF INTERMEDIATE PROCESSING OF EAST HAMPTON RECYCLABLES

Material Recovered	Amount (lbs)	Percent
Container II*		
newspaper	4,460	47.3
corrugated	700	7.4
mixed paper	4,220	44.7
rejects	52	0.6
	9,432	100.0
Container III**		
clear glass	1,831	39.5
amber glass	376	8.1
green glass	1,160	25.1
tin cans	731	15.8
aluminum	51	1.1
steel scrap	49	1.1
rejects	432	9.3
	4,630	100.0

*Sample representing 64% of the contents of the total amount of Container II material collected.

**The 4% difference between the weight of Container III given here and in Table V is due to loss of moisture and/or scale inaccuracies.

Table VII

EAST HAMPTON PILOT TEST RECYCLING EFFICIENCY

Percent of Component	Percent of Total Trash (a)	Percent of Total Component Rejected (b)	Percent of Material Rejected (axb)
Container I	32.9	5 (est.)	1.6
Container II	40.5	0.6	0.2
Container III	13.4	9.3	1.2
Container IV	13.2	100	13.2
Total			16.2

Table VIII

ANALYSIS OF EAST HAMPTON NON-RECYCLABLES
(CONTAINER IV)

Material	Sample #1 Percent	Sample #2 Percent
plastic	26.2	23.6
composites	13.9	12.6
disposable diapers	16.0	14.1
miscellaneous	8.4	10.7
mixed paper	7.6	13.2
textiles	7.1	6.3
compostable paper	5.8	4.7
potentially reusable	4.7	2.0
metals	3.4	3.1
leather & rubber	2.6	3.9
glass	1.8	4.1
potentially hazardous*	1.4	1.3
ceramics	1.1	0.4
Total	100.0	100.0

*primarily batteries

Note: The percentages are of materials sorted. 18% of Sample #1 and 14% of Sample #2 were not classified.

and processing of the paper/cardboard and bottle/can fractions. The data provided by these studies, together with evidence available from the literature, are summarized in the following assessments of the environmental impacts of these processing facilities.

a. Composting:

Properly conducted, a composting process produces no liquid emissions during primary composting; the environmental impact is due to possible odors and the emission of airborne materials. In the proposed Buffalo intensive recycling system, the food garbage fraction of the household-separated trash is to be brought to the compost facility in (closed) compactor trucks. Odors will of course occur when these trucks are unloaded at the facility. For that reason, unloading should take place within the building, which should be equipped to control air emissions, including odor.

The air forced through the compost during the initial composting process will carry microorganisms and volatile compounds out of it into the facility building. A study of the emissions from a cylindrical in-vessel Eweson digester at Big Sandy, Texas, indicated that the facility (30-ton capacity) emitted about 5 grams of volatile hydrocarbon compounds per hour -- a relatively low rate of emission (Guarino, 1985). More detailed analyses were carried out on the emissions from forced-air outdoor compost piles prepared from household-separated food garbage, yard waste and sewage sludge during the East Hampton study. Although these analyses are still incomplete, the data obtained thus far indicate that the emitted compounds are largely hydrocarbons that are expected to occur in the breakdown of organic materials. No toxic compounds have been detected.

The microorganisms found in the air emissions from East Hampton compost were not pathogenic, but were normal decomposition organisms such as those that occur in soil. Compost aeration may carry these organisms into the surrounding air. While the concentrations of viable organisms per unit volume of the air emitted by the forced-air system used to aerate the East Hampton compost piles were relatively high, they were all normal non-pathogenic soil organisms. There are reports in the literature that Aspergillus, a mold, may frequently occur in compost; this appears to be the only compost-related species that may have an effect on human health. A filter and scrubber on the air exhaust should control both odors and Aspergillus emissions. Compost serves as an excellent filtering material in emission control systems.

As noted earlier, composting requires a final maturation period, usually as a windrow in an open area. Because the organic matter that could cause odor and leachate problems has been digested away, maturation poses only minor environmental problems. Heavy rains could over-moisten the compost and lead to some anaerobic fermentation. Leachate from an over-moistened windrow would include low concentrations of organic acids; these would be readily oxidized by normal soil microbes. Such problems can be readily controlled by a leachate collection system.

b. <u>State standards for composting facilities</u>:

The compost facility must meet general waste disposal facility standards for health and safety. New York State requires that all waste disposal facilities, including composting operations, have a permit to operate (NYS DEC, 1987c). This permit requires that any leachate from the composting operation not enter surface waters. Conditions must be maintained so that litter is not blown off site and odor is not an off-site problem.

The only State standard to address the question of compost microbial populations is directed toward compost that contains sewage sludge. This requires that the compost be subject to a Process to Further Reduce Pathogens (PFRP), for example, by remaining for at least three days at 55oC or more. Compost that contains sewage sludge cannot be used on food crops acreage, according to the draft State regulations on compost of January 1, 1985, and is subject to limits on heavy metals (cadmium, chromium, mercury, nickel, lead and zinc), and on PCBs.

Current New York State requirements for compost processing are as follows (NYS DEC, 1987c):

(i) Solid waste shall be maintained in an aerobic environment for sufficient time to ensure stabilization and pathogen reduction.

(ii) Adequate space for storage of the completed compost shall be available.

(iii) Analysis of completed compost shall be performed on a regular basis as determined by the Department.

(iv) Market or use of completed compost may be limited through permit conditions, subject to the quality of the compost.

(v) All noncomposted material and compost not of a quality fit for land application as determined by the Department shall be disposed in a facility approved by the Department.

A composting facility for the Buffalo intensive recycling system designed as indicated in Section III.C.1. could readily comply with the State's standards on aeration and adequate storage space. The other three standards impose operational requirements (compost analysis, market targeting, and proper disposal of rejects) that are also readily satisfied. If no sewage sludge is used in the compost, possible regulatory problems with toxic metals and pesticides would be avoided, as well as possible market limitations by the State. The State standards, as currently drafted, would not pose a heavy burden on the proposed composting program.

c. Processing of paper/cardboard and bottles/cans:

The possible environmental impacts of MRFs are generally limited to air emissions. The East Hampton study analyzed air emissions from the RRS facility in Groton, CT, during routine processing operations on bottles/cans and paper/cardboard. Air drawn from the plant was analyzed for dust particles, volatile organic compounds, and bacteria during several cycles of operating and non-operating periods. The metal content of the dusts and toxic metal concentrations in the facility air were lower than the occupational limits. Organic chemicals in the air were also sampled. Relatively high concentrations of isobutane, freon (trichlorofluoromethane), 1,1,1-trichloroethane, total xylenes, and methylene chloride were found in some but not all samples.

Results of sampling the RRS facility at Groton, CT, also showed that appreciable concentrations of bacteria were found in the air. They were not primary pathogens (that is, normally disease agents), but types of organisms found commonly on old food and on materials touched by human skin. The concentrations were equal to or less than those found in sewage treatment plants. Although neither the detected bacteria nor emitted chemicals pose a threat of disease, if desirable, emissions of both can be controlled. Activated charcoal filters or chemical scrubbers can be used on exiting air to remove organic compounds. Ultraviolet light, filters, or a disinfectant in the chemical scrubber can be used to reduce viable populations of microorganisms.

The occupational health program of intermediate processing facilities should address both the mineral and microbial dusts and the noise from the machinery. If the machinery is not engineered to contain the dusts, respiratory protection should be provided to the workers. Isolation of the workers from the recycled cans and bottles by a ventilation system with hoods above the conveyor belts and machines could also greatly reduce exposure to dusts and bacteria. If the noise exceeds the OSHA limits for an eight-hour day or for immediate ceilings, hearing protection must be provided. The machinery must have the proper safety guards as well. Gloves must be provided to workers handling the materials to preclude cuts from glass and metal and dermatitis from, for example, newspaper ink.

D. Markets for Recycled Products:

The intensive recycling system can succeed as a means of waste disposal only if its products are used, and therefore do not accumulate. Hence, in designing the system, it is necessary to determine whether there is an existing (or, if this is not sufficient, a potential) demand for the system's products: compost, separated grades of paper and cardboard, color-sorted crushed glass, aluminum cans and foil, tin cans and scrap steel. The demand should be located as close as possible to Buffalo in order to avoid excessive transportation costs.

The price at which each product can be sold will vary with market conditions and transportation costs. Characteristically, the market price for recycled products ("secondary" materials) must compete with the price of virgin, primary materials and will generally be significantly lower than the latter. For the intensive recycling system, the crucial factor is not so much price as demand, for variations in price will be absorbed in the net cost of the system as a whole. Simply stated, what is important is to dispose of the system's products, regardless of price; naturally, it will be advantageous to obtain the best possible price. What is at issue, therefore, is to determine whether the demand for the system's products are large enough to absorb the amounts of the various products that the system is expected to yield. In what follows we estimate demand and compare it with the expected output of recycled products from a Buffalo intensive recycling system. The estimates are based on inquiries to firms that are now purchasing such products, or to agencies that are familiar with such information. (See Appendix F for list of these sources of information.)

1. <u>Compost</u>:

Compost is well established as a useful soil additive that improves moisture-holding capacity and porosity, and provides plant nutrients. Commercial soil additives are generally available in the form of top soil, peat, peat moss and wood chips; compost prepared from leaves and yard waste is also in general use. Projected annual production of compost from the Buffalo intensive recycling program will be approximately 90,000 cubic yards. It is expected to be equal in quality to commercial soil additives and therefore capable of substituting for them. In what follows we estimate the market for soil additives in the area within about 20 miles of Buffalo in order to determine the degree to which it could absorb the compost output of the proposed intensive recycling system.

a. Landscape services:

Commercial landscape operations have a continual need for organic soil supplements, which is, of course, seasonal. There are more than 100 landscape service firms in Erie County; at least 50 to 75 of them are major firms employing 10 to 15 people each. Average annual consumption of top soil, sedge peat, peat moss and wood chip mixtures is estimated at 3,000 cubic yards per major firm, or a total of approximately 150,000-225,000 cubic yards.

b. Field nurseries:

There are six major field nursery firms with about 1,800 acres of in-ground ornamentals in the Buffalo area. They generally apply about 500 cubic yards of soil additive per acre every third year, or 167 cubic yards annually. Thus, the potential annual demand is about 300,000 cubic yards.

c. Container horticulture firms:

These firms grow ornamental plants and shrubs in containers for sale. There are four major container horticulture firms in the Buffalo-Erie County region, with a total working area of 30 to 35 acres, and an average of 40,000 two-gallon containers per acre. Total potential for growing medium is therefore approximately

12,000 cubic yards. Since about one-third of the growing medium generally consists of peat or a pearlite/composted-leaf equivalent, it can be estimated that compost demand from these operations may be about 4000 cubic yards per year.

d. Greenhouse operations:

There are 80-100 greenhouses that produce flowers and potted plants in Buffalo and the surrounding area. They cover a total of about 75 acres and require a total of approximately 600 cubic yards of growing medium annually. About half of this, or 300 cubic yards, is traditionally peat products, which could be replaced by Buffalo compost.

e. Fresh-market vegetable growers:

There are about 1,200 to 1,500 acres under cultivation in Erie County for fresh-market vegetable production. Soil used in such production must be well supplied with nutrients and well drained -- properties that require regular upgrading with soil additives such as compost or peat. State regulations establish quality standards for such application; the compost produced by the Buffalo intensive recycling system is expected to meet these standards. It is estimated that an application of about 150 cubic yards of soil additives per acre -- a layer about four inches deep -- is most beneficial every three years. This would result in a 60,000 cubic yard annual demand, based on an average loading rate of 180,000 cubic yards every three years.

f. Small fruit growers:

The requirements for small fruit production (strawberries, raspberries and blueberries) are similar to those of vegetable production -- about 150 cubic yards per acre of soil additive applied every three years. The estimated 1,000 acres regularly under cultivation for small fruit production in Erie County represents a potential demand of about 50,000 cubic yards annually.

g. Public parks and recreational areas:

Public parks in Buffalo and Erie County comprise more than 18,000 acres of land. City parks make up nearly 1,100 acres; county parklands, nearly 10,000 acres; and state park properties, 7,595 acres. These areas include playgrounds, athletic fields, golf courses, hiking trails, flower beds, ornamental shrub arrangements, and a botanical garden. Municipal, county and state park managers report a need for soil amendment materials such as compost, though total consumption is modest -- less than 1,000 cubic yards per year.

h. Other uses:

Disturbed lands in Buffalo and Erie County such as landfill closures and sites disturbed by construction projects will require some form of landscaping, and therefore some use of soil additives. Soil additives are also used on the grounds of public buildings. These operations are an additional potential market for compost, of undetermined but probably small size.

i. Total market:

The total existing market for compost in the Erie County area is summarized in Table IX; it is approximately 600,000 cubic yards or about 240,000 tons per year. The anticipated annual production of compost by the Buffalo intensive recycling system is 90,000 cubic yards, or 36,000 tons. The largest potential markets are in field nurseries and landscape services. Hence, the existing

Table IX

LOCAL COMPOST MARKETS

Activity	Estimated Demand (tons/yr)*
Landscape services	75,000
Container horticulture firms	1,600
Field nurseries	120,000
Greenhouse operations	120
Fresh vegetable production	24,000
Small fruit production	20,000
Public parks	400
Erie County Total	241,120
Niagara County**	24,110
Total	265,230

*Computed from the number of firms multiplied by the average use per unit firm. Conversion ratio: 2.5 cubic yards per ton.

**Niagara County is conservatively estimated to have a market equal to about 10% that of Erie County.

<u>Sources</u>: Responses from Agriculture Extension Agent, Erie County; Parks Commissioner, City of Buffalo; Niagara Frontier State Park Commission; and the Erie County Commissioner of Parks. See Appendix F for names and addresses.

million in 1982 for similar operations in Erie County. It is conservatively estimated that the Niagara County market is at least 10% of that in Erie County, or nearly 24,000 tons per year.

2. Glass:

Glass container manufacturers have found that the addition or substitution of scrap glass to the virgin materials such as sand used in manufacturing glass containers cuts energy requirements and furnace deterioration. Operating costs are thereby reduced. However, scrap glass must be "furnace-ready": color-separated, crushed and nearly free of contaminants. This means that the intensive recycling system materials recovery facility must separate glass containers according to color: clear (or "flint"), amber (or "brown"), and green. (Glass mixed by color can be used in other less established markets, e.g., fiberglass or glassphalt.) The crushed, color-separated "cullet" must be free of refractory (high melting point) materials that may occur in trash, such as ceramics, brick, mortar, stone, and dirt, and non-homogeneous glass products such as mirrors or light bulbs. Container manufacturers' quality specifications are nearly identical. Flint glass is in greatest demand at present.

The market for color-separated glass cullet within 150 miles of Buffalo is summarized in Table X. It is based on the amounts of cullet that the indicated firms are willing to use in their present facilities. The market for flint is about 209,000 tons per year; for amber, about 100,000 tons per year; and for green, about 60,000 tons per year. Although Consumers Glass states that it is primarily interested in green cullet from Ontario, their market could probably be penetrated if the quality and price are market appears to be sufficient to absorb the annual compost output of the system.

Demand will be a function of what price is charged for the compost. The price will need to compete with the cost of commercial soil additives; peat currently sells for about $30-$40 per ton ($12-$16 per cubic yd.) in the Buffalo area. Until a steady market demand is established, it may be expedient to make the compost available initially at no cost or a nominal one. Compost prepared from food garbage and yard waste is currently marketed in a number of European communities.

Promotional activities will help to develop the initial market for compost. For example, the City could demonstrate the usefulness of the product by substituting it for present purchases of soil additives, such as peat. In addition, special projects aimed at demonstrating the value of the compost as a plant cultivation medium could be sponsored by the City, local garden clubs, and other civic organizations.

These considerations suggest that the existing market for soil additives in Erie County would readily absorb the compost output of the Buffalo intensive recycling system. Additional potential markets could be developed as well. Potential markets include private golf courses/country clubs, colleges and universities, corporate industrial parks, shopping malls, and local residential use. There are additional potential compost markets in neighboring Niagara County. According to the Niagara Co. Agriculture Extension Office, there are some 70 nursery and greenhouse establishments in the county which in 1987 had almost $3 million in sales, as compared with total annual sales of $10

Table X

LOCAL GLASS MARKETS

Firm	Maximum Demand* (tons/year) Flint	Amber	Green	Price Range ($/ton)	Approximate Trucking Distance
Anchor Glass Elmira, NY	25,000	25,000	0	55-60	130 miles
Central NY Bottle Auburn, NY	30,000	10,000	0	50-54	120 miles
Consumers Glass Toronto, Ontario	80,000	30,000	35,000	32-65	100 miles
Domglas Hamilton, Ontario	54,000	15,000	15,000	32-40	50 miles
Owens-Illinois Fulton, NY	20,000	20,000	10,000	15-50	150 miles
Totals	209,000	100,000	60,000		

*Based on capacity of existing facilities and maximum use of cullet in glass production.

Source: Telephone interviews with company representatives, March 1988. See Appendix F for names and addresses.

competitive. The Buffalo intensive recycling system is expected to produce about 6,410 tons per year of flint, 1,320 tons per year of amber, and about 4,160 tons per year of green. The market appears to be capable of absorbing this output.

3. <u>Metals</u>:

Metallic scrap recoverable from the Buffalo recycling program includes tin cans, aluminum cans, foil and scrap, and steel scrap.

"Tin cans" are steel cans electroplated with a thin coating of tin. The tin coating can be chemically removed and reused; the can is then regarded as high-grade steel scrap, which can be re-smelted by the steel industry. The Steel Can Recycling Association (SCRA), made up of five major U.S. steel companies, has recently been organized to facilitate recovery of detinned cans. The Canadian Tinplate Recycling Council has a similar purpose.

Three types of recoverable aluminum are anticipated in the output of the proposed intensive recycling system: cans, foil and other scrap. Despite the New York State law requiring a deposit on beverage containers, a proportion of those containers are never redeemed and some aluminum beverage cans can be expected in the trash stream. The market for aluminum cans or "UBCs" (used beverage containers) also includes other aluminum food and beverage containers which are non-deposit, as well as discarded aluminum foil scrap and other scrap items such as discarded cooking pots.

The market for metals is summarized in Table XI. Although local aluminum firms did not provide capacity data, the industry is now in the practice of accepting all offered aluminum cans, so

Table XI

LOCAL METALS MARKETS*

Firm	Capacity (tons/yr)	Price Range (dollars/ton)	Material	Approximate Trucking Distance
Alcan Cleveland, OH	na	1,460-1,480	UBCs	130 miles**
ALCOA Edison, NJ	na	1,320-1,400	UBCs	40-60 miles***
AMG Resources Pittsburgh, PA	360,000	80-85	tin cans	215 miles
Metal Recovery Hamilton, Ontario	35,000	40	tin cans	50 miles
Reynolds Hartford, CT	na	200-1,400	UBCs, foil alum. scrap	375 miles
steel industry	350,000	20-60	scrap	100 miles or less
Tin market	395,000			
Steel market	350,000			
Aluminum market	unlimited			

Notes:
na = not applicable; aluminum markets virtually unlimited.
UBCs = "used beverage containers," or aluminum cans.

* Purchasers of steel products are not listed. There are more than 100 scrap dealers in the 716 telephone area code.
** Alcan has a smelting plant in Oswego, NY.
*** ALCOA's local accounts (brokers) are in Jamestown and Dunkirk.

Source: Telephone interviews with company representatives, March 1988. See Appendix F for names and addresses.

that the output of the Buffalo system can readily be absorbed. The local market for tin cans, about 400,000 tons/year, is also considerably larger than the expected output of the Buffalo system, about 2,650 tons/year. The same is true of scrap steel.

4. Paper:

Marketing of paper recovered from trash is greatly affected by its quality. This depends on the type and uniformity of the material and the absence of contaminants, such as food, oil, plastic or metal. The proposed Buffalo intensive recycling system will yield three basic categories of material: newspapers, cardboard and mixed paper. Mixed paper is presently regarded as a low-value commodity. This is due to the uncertainty of contaminating materials that it may contain, such as plastic envelope windows, adhesive labels, foil inserts, metal staples and fasteners. In contrast, certain grades of office and computer paper are given much higher values because of the quality of their fibers. The demand for old newspapers and corrugated containers remains robust.

On the basis of a telephone survey, we have identified a series of firms within 125 miles of Buffalo that will receive the paper and cardboard products of the proposed intensive recycling system. Their capacities and the materials they accept are presented in Table XII. These markets are much larger than the expected rate of generation by the intensive recycling of newspapers (about 13,910 tons/year) or corrugated (3,640 tons/year). Mixed paper, generated at 21,940 tons per year, would nearly fill the current local market for this commodity. However, this does not take into account the large export market for mixed

TABLE XII

LOCAL PAPER MARKETS*

Firm	Capacity (tons/yr)	Material	Approximate Trucking Distance
Atlantic Packaging Scarborough Ontario	75,000	OCC	125 miles
Beaverwood Fibers Thorold, Ontario	50,000 50,000	OCC ONP	25 miles
Cascades Paper Niagara Falls, NY	70,000	ONP	15 miles
Domtar St. Catherines	16,000 3,000	OCC M	25 miles
and Toronto, Ontario	3,000	M	100 miles
IKO Industries Brampton, Ontario	28,000 12,000 6,000	M OCC ONP	100 miles
Niagara Fiberboard Lockport, NY	20,000 20,000	OCC ONP	20 miles
Ontario Paper Thorold, Ontario	150,000	ONP	25 miles
Paperboard Industries Toronto, Ontario	900 4,500 2,200	M OCC ONP	100 miles
U.S. Gypsum Oakfield, NY	2,200 22,500	ONP OCC	30 miles

TOTAL MARKET:

Newspapers (ONP)	300,400	tons/yr
Corrugated (OCC)	200,000	tons/yr
Mixed (M)	34,900	tons/yr

OCC = old corrugated containers, ONP = old newspapers, M = mixed

* Listing includes only mills in the 416 and 716 area codes which use secondary fiber. Mixed paper markets are handled primarily by paper brokers of which there are more than 25 in the same region. Prices are derived from brokers and range $5-$10 for mixed, $15-$45 for ONP, and $15-$55 for OCC.

SOURCE: Telephone interviews with company representatives, March 1988. Please see Appendix F for names, numbers and additional contacts.

paper, particularly the Far East. Such shipments could readily be made through Great Lakes and East Coast ports. This market, utilized with success in Camden, NJ, and Groton, CT, should be further explored.

5. Market penetration:

The estimated local markets for the materials recoverable from the Buffalo intensive recycling system are compared with the system's expected output in Table XIII. Except for mixed paper, green glass and compost, the system's output requires only a very slight penetration into the existing local markets. Because the local, domestic market for mixed paper is currently limited, the output from the Buffalo system would represent about 63% of this market. However, there is an essentially unlimited market for mixed paper overseas, which is accessible to the Buffalo area via the St. Lawrence Seaway or East Coast ports. This market could be used to dispose of the mixed paper output as dictated by prevailing market conditions. The Buffalo system's output of green glass cullet represents about 7% of the existing local market. Canadian demand, which represents the greatest market, will be affected by increases in cullet output from Ontario-based curbside collection programs. Nevertheless, at least one U.S. company, Owens-Illinois, is committed to purchasing all of the glass its current accounts can supply.

In sum, the output of secondary materials that the Buffalo intensive recycling system is expected to produce could be absorbed by the existing markets for secondary materials with no undue difficulty.

Table XIII

Relation Between Local Markets and Intensive Recycling System Product Output

Material	Estimated Local Market Capacity (tons/yr)	Current Price Range ($/ton) E)	Estimated Intensive Recycling System Product Output (tons/yr) H)	% Market Penetration Required I)
Paper				
Newsprint	A) 300,400	15-45	13,910	4.6%
Corrugated	200,000	15-55	3,640	1.8%
Mixed	34,900	5-10	21,940	J) 62.9%
Glass				
Flint	B) 209,000	40-65	6,410	3.1%
Amber	100,000	40-60	1,320	1.3%
Green	60,000	F) 15	4,060	6.8%
Metals				
Aluminum:				
UBCs*	C) na	1320-1480	60	na
Foil	na	200-300	110	na
Scrap	na	600-1000	10	na
Steel:				
Tin Cans	395,000	40-85	2,560	0.6%
Scrap	350,000	20-60	170	0.05%
Compost				
Compost	D) 265,230	G) 5	36,000	K) 13.6%

* "UBCs" = "used beverage containers," or aluminum cans. "na" = "not applicable."

A) Paper market capacity is based on the current annual waste paper consumption reported to CBNS by existing paper mills in telephone area codes 716 (Western New York) and 416 (Southeast Ontario). Estimates therefore do not include the expansive paper markets beyond this region and overseas. Of the five paper brokers contacted, total shipments of approximately 360,000 tons per year were reported. This represents a fraction of the total transactions of the more than 25 brokers in the area.

B) Glass manufacturing capacity is based on estimates for potential cullet use reported by glass companies within 150 miles of Buffalo.

C) The market for aluminum scrap is virtually unlimited. Steel scrap markets are limited in this estimate to the U.S. and within 100 miles of Buffalo. Delivery to Pittsburgh, Pennsylvania or Hamilton, Ontario is assumed for tin-plated steel cans.

D) This potential market should also include all public lands and private properties with in-house landscaping and lawn-care staff. They are omitted in this calculation because potential compost use estimates are presently unavailable. A conversion factor of 2.5 cubic yards per ton is used. The estimate is for Erie and Niagara counties.

E) Prices are based on a survey of Buffalo area secondary materials brokers and industries.

F) Green cullet is purchased by Consumers Glass at $40 (Canadian) per ton. While Consumers' purchasing is limited primarily to Canada, their price may indicate that US demand is understated.

G) Current prices for peat range from $12 to $16 per cubic yard, or $30 to $40 per ton. As a product of comparable quality, Buffalo compost is expected to sell for a minimum of $5 ton.

H) These tonnages are based on a projection of a 90% participation rate in a city-wide municipal waste recycling program (See: TABLE XXVIII).

I) Market penetration estimates are achieved here through the division of the "Estimated Intensive Recycling System Product Output" by the "Estimated Local Market." Therefore, percentages indicate what proportion of the current local market must be acquired in order to dispose of collected materials.

J) Market penetration estimates for paper assume local mills only. The five Buffalo area paper brokers contacted for this report all agreed that markets could be found for all paper recovered.

K) Numerous additional uses of the compost are described in SECTION III.D. and not quantified here. Actual market penetration estimates for compost should therefore be appreciably less than 13%.

IV. PROPOSED BUFFALO INTENSIVE RECYCLING SYSTEM: SPECIFICATIONS

A. Household Separation:

1. Four containers:

Container I (food garbage/yard waste): paper bag inside bucket
Container II (paper/cardboard): box or paper bags
Container III (bottles/cans): bucket
Container IV (non-recyclables): plastic bag

2. Recycling kits:

two six-gallon plastic buckets with lids
one 11-gallon plastic box
one set of container logos
one diagram of "where things go"
one recycling information flier

B. Collection System:

1. Vehicles:

Unit 1: 20 cubic yard compactor truck (food garbage/yard waste)
14 cubic yard compactor trailer (non-recyclables)

Unit 2: 14 cubic yard compactor truck (paper/cardboard)
10.5 cubic yard non-compacting trailer (bottles/cans)

Number: 33 of each unit

2. Collection procedures:

- crew: 1 driver, 2 loaders
- crews per route: 2
- route length: 12.5 miles (average)
- time per shift: 6 hours, 15 minutes (1 hr overtime)
- total number of routes: 280 (56 per day)
- total number of crews: 112

C. Processing Facilities Specifications:

1. Compost plant:

Operating time: 260 days/year

Input capacity (tons/day)
- food garbage = 170
- yard waste (peak) = 200

Anticipated compost output (90% participation; cu.yd./day):
- average = 346
- peak = 480
- winter = 220

Approximate rejection rate = 8.3% of input

Process:
1. Waste reception (closed area with odor control)
2. Hand-picking (picking belt) of rejects
3. Magnetic separation of ferrous rejects
4. Grinding
5. Primary composting; enclosed reactors; forced aeration; odor control. Minimum process time = 7 days. Process temperature = 55-60°C
6. Screening (10 mm screen)
7. Maturation (piles): minimum process time = 6 weeks Front-end loader for materials handling.

Location: near East Transfer Station

Site area (storage not included): 3 acres

Compost storage area: 2 acres

2. <u>Materials Recovery Facility</u>:

Operation time: 260 days/year

Input capacity (tons/day):
- paper/cardboard = 170
- bottles/cans = 70

Products:
- newsprint
- corrugated
- household mixed paper
- flint glass cullet
- amber glass cullet
- green glass cullet
- tin cans
- bimetal cans
- aluminum cans
- aluminum foil & scrap
- steel scrap

Approximate rejection rates:
- paper/cardboard processing = 1% of input
- bottle/can processing = 5% of input

Process:

Paper/cardboard:
1. Waste reception
2. Hand-sorting from belt
3. Baling

Bottles/cans:
1. Waste reception
2. Combination of hand-sorting, magnetic, gravitational and other types of mechanical separation

3. Crushing and refining of glass; cans flattened; and other products baled. Refining means removal of other materials such as labels and metal tops.

Appropriate building size: 26,000 sq. ft.

Appropriate area of site: 3 acres

V. COST ANALYSIS OF ALTERNATIVE BUFFALO SOLID WASTE MANAGEMENT SYSTEMS

As noted earlier, the cost of the City's present system of trash management is certain to increase significantly in the immediate future, largely because of the environmental impact of the ultimate disposal processes -- incineration and landfilling. The proposed intensive recycling system significantly reduces these environmental hazards. The remaining question is whether the proposed system is also less costly than the City's present trash management system. In order to answer this question, we have compared the costs of the proposed intensive recycling system with the City's present system in the year 1991, when the new system could be expected to be in full operation. All costs are computed in constant 1987 dollars.

A. Basic Assumptions of the Cost Analysis:

Throughout this economic analysis certain assumptions are made that are designed to facilitate optimum operation of the intensive recycling system (for example, that 90% of the Buffalo households will actually participate in the necessary trash separation). In computations reported in Appendix G we vary all but one of these assumptions and perform a sensitivity analysis to determine how these less than optimum conditions affect the system's performance.

1. Amount and composition of refuse:

The amount of refuse generated per person in the United States has risen historically. However, because Buffalo has been losing population, we assume that the amount of trash generated per year will be stable for the near future. We also assume that its composition will remain roughly stable.

For purposes of calculating the net costs of dealing with Buffalo's municipally collected trash, we assume that bulky waste will continue to be picked up and dealt with separately. We do not include these costs in this analysis, although recycling and reuse can make a potentially large reduction in the amount of bulky waste that is disposed of. We do not possess enough data about the composition, collection or current disposal of bulky waste to assume otherwise. The overall collection and processing or disposal costs developed in this analysis thus apply to regular household waste.

Furthermore, we assume that separate collection of household hazardous waste will become a reality no matter what system is adopted. These costs are also not included in the comparative analysis either.

2. Participation rate:

We assume a participation rate of 90%. This means that 90% of the households separate their trash with an efficiency equal to that found in the East Hampton pilot test. Although this value is optimistic, we believe it is achievable. Participation rates of 90% and higher have been achieved for other mandatory recycling systems (Pettit, 1986). In the survey of three neighborhoods conducted by CBNS and Citizen Action, we found that 80% of the respondents were willing to recycle, even though an educational campaign was not conducted. With a full-scale educational program, mandatory requirements, and positive incentives, a high value should be attainable. We also conservatively assume that non-participants do not separate at all; all of the waste they generate is considered non-recyclable.

3. <u>Collection parameters</u>:

The key assumptions about the collection process are the amount of additional time required to collect materials using the intensive recycling system (that is, above the time required in the present system) and the amount of additional work time required per employee. As was shown earlier, these assumptions turn specify the number of employees, as well as the number and size of vehicles.

4. <u>Tipping fee</u>:

The current tipping fee charged by BFI for municipally collected refuse in Buffalo is about $20 per ton. This covers BFI's costs of ultimate disposal of the trash to incineration or landfilling, and of landfilling the incinerator ash. For reasons given in Section I, this tipping fee is expected to rise to about $60 per ton by 1991. This figure is used for both systems in the cost comparison to account for the cost of landfilling of non-recyclables and rejects from intensive recycling, as well as for incineration/landfilling of the current system's trash. This may overestimate the tipping fee for intensive recycling because there will be no incinerator ash, which is likely to require more costly disposal.

5. Prices of recyclable materials:

The prices assumed here are based on a survey of current markets in the Buffalo area. Since they are local markets, a nominal cost of $5 per ton for transporting the products of the materials recovery facility to the purchasers is included in the operating costs of the facility. If other markets are actually used, the transportation cost will rise, decreasing the return. We have not taken into account elasticity of demand or fluctuation of prices with national and international economic conditions. These possibilities are dealt with by using low and high recycling prices in the sensitivity analysis.

B. Collection Costs:

Collection costs depend on the physical and mechanical features of the collection system: equipment specifications; collection procedures; and labor requirements. For the current system, the necessary information about these factors is available from the City budget, augmented by additional material kindly supplied by the Commissioner of Street Sanitation. The analagous data for the proposed intensive recycling system were derived from the specifications presented in Section IV above, using the computational methodology described in Appendix G.

1. Equipment:

Table XIV shows the equipment needed for collection in both the present and proposed systems. The current capital stock of trucks is of varying ages, the oldest being nine years old. In the proposed intensive recycling system the current stock of trucks will be gradually replaced by two truck-trailer combinations. The recycling kits specified in Table XIV for the

Table XIV

COLLECTION EQUIPMENT REQUIREMENTS

Description	Present System	Intensive Recycling System
Number of 25 cu.yd. compactor trucks	59	Ø
Number of 14 cu.yd. compactor trucks	Ø	33
Number of 2Ø cu.yd. compactor truck/ 14 cu.yd. compactor trailers	Ø	33
Number of 1Ø cubic yard trailers	Ø	33
Number of recycling kits provided	Ø	17Ø,ØØØ

Notes:

The number of collection vehicles in both systems is 18% higher than the minimum needed to cover refuse collection routes. The extra trucks provide for routine maintenance of the fleet.

Recycling kits include educational materials and household/ curbside containers for recyclables. Enough are provided for 12Ø% of the households in the City of Buffalo.

intensive recycling system (120% of the number of Buffalo households) will initially be provided by the City, and are included in the calculation of one-time-only capital outlays. After the initial stock of kits is depleted, the City would continue to provide the educational materials included in the kits upon demand.

2. Collection procedures:

The current collection procedures specified in Table XV are based on data provided by the City Department of Street Sanitation. Certain of these data differ from information in the City of Buffalo Budget, due largely to the differences between the official definitions of job function and the actual tasks that the employees do. Section IV summarizes the assumptions used to specify the intensive recycling collection system (see also Appendix G). Collection is modified so that two crews pick up trash from each household. Since each crew picks up less material, the route length can be extended. The key assumptions are the amount of extra time needed for collection, and the amount of overtime required (time per crew above current needs).

Labor specifications are based upon estimates of labor required to operate the present collection system. Increases in the amount of labor for the intensive recycling system were the result of changes made in truck requirements (presented in Appendix C). Labor specifications are shown in Table XVI.

The per-unit costs of collection for the present and proposed systems are presented in Table XVII. Equipment costs are estimated from price quotes obtained from manufacturers and dealers of refuse collection equipment. Labor costs are based on

Table XV

COLLECTION ROUTE SPECIFICATIONS

Description	Present System	Intensive Recycling System
Number of routes	100	56
Average length of routes in miles	7	12.5
Number of crews	100	112
Number of staff per crew	3	3
Number of crews per route	1	2
Time from garage to route in minutes	20	20
Driving time on route in minutes	60	107.1
Pickup time on route in minutes	120	133.9
Driving time from route to transfer station to garage in minutes	75	75
Time spent unloading at transfer station and doing other work	40	40
Average total time worked per route in minutes	315	376

Note: These estimates are based on an increase in overall collection time of one hour. See Appendix C for sources of specifications.

Table XVI

LABOR SPECIFICATIONS FOR COLLECTION

Description	Present System	Intensive Recycling System
Number of truck drivers	100	112
Number of sanitation workers	100	112
Number of laborers	100	112
Number of supervisory personnel	11	11
Recycling coordinator	0	1
Recycling educator	0	1
Office of Recycling support staff	0	2

<u>Note</u>: Stated number of personnel in the City of Buffalo budget is lower than our estimates of the personnel needs for refuse collection in the city. This discrepancy is due to uncertainties about the actual tasks of some personnel listed in the Budget, and to lack of specific data on overtime by Dept. of Street Sanitation personnel.

Table XVII

PER UNIT COSTS OF COLLECTION

Description	Cost
25 cubic yard compactor truck	$105,000
18 cubic yard compactor truck*	$ 40,000
10 cubic yard trailer	$ 6,000
20 cubic yard compactor truck with 14 cubic yard compacting trailer	$ 95,000
Household recycling kit	$ 12
Truck driver - annual salary**	$ 19,443
Sanitation worker - annual salary**	$ 19,405
Laborer - annual salary**	$ 18,522
Supervisor - annual salary**	$ 22,700
Recycling Coordinator - annual salary	$ 20,520
Recycling office support staff - annual salary	$ 16,376
Recycling Educator	$ 19,500

*An 18 cubic yard compactor truck is available at less cost than the 14 cubic yard compactor truck, which is the capacity required for collecting paper for the intensive recycling system.

**Annual salaries are calculated on the basis of the 1987 pay scale for Buffalo city employees. It is assumed that new employees start at the bottom of the scale for each occupational category.

average pay scales, in constant 1987 dollars, from the City Budget.

The annual capital outlays for the present and proposed systems are shown in Table XVIII. The present system costs are based upon a proportional share of the Capital Outlays budget for the Department of Street Sanitation. An average annual figure was calculated from yearly appropriations for the purchase of capital equipment for refuse collection, inflated to constant 1987 dollars and averaged for a six-year period (fiscal 1982/83 to 1987/88). Capital outlays shown for the intensive recycling system represent equipment replacement after the system has been established. The cost of initial purchases of the new equipment needed to establish the intensive recycling system are considered below.

The average annual operating outlays for the two systems are shown in Table XIX. For the present system, these were calculated by multiplying the six-year average annual DOSS operating and administrative appropriations by the ratio of collection capital costs to total capital costs. Operating collection costs for the intensive recycling system were based on the foregoing figures, adjusted to account for differences between the two systems that affect equipment life, operating hours per year, and price. This calculation is presented in detail in Appendix G.

As shown in Table XIX, operational outlays for the intensive recycling system are $1,046,500, a 34.4% increase in the operational costs over those of the present system. This increase is due to larger costs for administration, radio control and mechanical and repair services. The increase also includes

Table XVIII

ANNUAL CAPITAL OUTLAYS FOR COLLECTION

	Present System No.	Present System Cost	Intensive Recycling No.	Intensive Recycling Cost
Number of trucks purchased:				
25 cubic yard trucks	5	$545,000	0	0
18 cubic yard trucks	0	0	4	$156,400
Number of trailers purchased:	0	0	4	$ 23,450
Number of truck/compactor trailers	0	0	4	$371,450
Number of trash cans (for city streets)	500	$ 5,000	2000	$ 20,000
Total		$549,950		$571,300
Cost per ton of trash collected		$3.68		$3.82

Note: Annual capital outlays are budgeted for the replacement of the collection vehicle fleet. Under the current system of collection, the trucks have an assumed lifetime of 11.37 years, and under the intensive recycling system, trucks have a lifetime of 8.44 years.

Table XIX

COLLECTION SYSTEM OPERATING COSTS

	Present System	Intensive Recycling System
Administrative services	$ 90,600	$ 119,700
Radio control	$ 55,200	$ 61,800
Mechanical services	$ 48,400	$ 54,100
Auto repair services	$584,200	$ 591,000
Office of Recycling	0	$ 100,000
Advertising Budget	0	$ 120,000
Total Operating Costs	$778,400	$1,046,500
Cost per ton of trash collected	$5.20	$7.00

Note: See Appendix G for details.

outlays for two new intensive recycling system services: the Office of Recycling and advertising. These new activities are essential for the educational program that must accompany intensive recycling.

Annual personnel outlays for both systems are presented in Table XX. In the intensive recycling system, both the amount of time worked and the number of employees increase. The cost of the increased work time has been computed as an increase in overtime, with employees receiving time and a half for the overtime hours. The new employees are added because extra crews are required by the intensive recycling system. New employees are also required to staff the Office of Recycling.

In order to establish the new intensive recycling system, it will be necessary to incur one-time costs to purchase new equipment and supplies. These costs have been computed as follows.

One-time-only capital costs are calculated by estimating the total costs of replacing the current fleet of collection vehicles with the vehicles specified for the intensive recycling system. These costs cover the initial purchase of 33 compactor truck/trailer units, 33 smaller compactor trucks, and 33 trailers. It is assumed that up to 14 of the old trucks would be sold in order to recoup some of this expense. This initial purchase also includes the purchase of 170,000 recycling kits (see Section IV, specifications). One-time-only costs include an extra expenditure for advertising and promotion of recycling. The total initial expenditures for the implementation of intensive recycling is estimated at $5,292,000. Using an estimated equipment lifetime of

Table XX

ANNUAL COLLECTION PERSONNEL COSTS
(EXISTING EMPLOYEES)

	Present System No.	Present System Cost	Intensive Recycling No.	Intensive Recycling Cost
Number of drivers	100	$1,944,300	100	$1,944,300
Number of sanitation workers	100	$1,940,500	100	$1,940,500
Number of laborers	100	$1,852,200	100	$1,852,200
Number of supervisors	11	$ 249,700	11	$ 249,700
Benefits (@ 38.75%)		$2,319,800		$2,319,800
Total	311	$8,306,500	311	$8,306,500
Increase in time worked	0%		20%	
Increased personnel costs		0		$1,706,200*
Total costs		$8,306,500		$10,012,800
Total cost per ton of collected trash		$55.53		$66.94

*20% increase in time worked. Personnel paid at overtime rates (time and a half).

Table XXa

ANNUAL COLLECTION PERSONNEL COSTS
(ADDED EMPLOYEES)

	Present System No.	Present System Cost	Intensive Recycling No.	Intensive Recycling Cost
Number of new drivers	--	--	12	$ 211,380
New sanitation workers	--	--	12	$ 208,728
New laborers	--	--	12	$ 196,176
Recycling coordinator	--	--	1	$ 20,430
Recycling educator	--	--	1	$ 19,500
Recycling office support	--	--	2	$ 32,752
Benefits (@ 38.75%)	--	--	0	$ 266,940
Total	0	0	40	$ 955,900
Total personnel costs (Existing & Added)	311	$8,306,500	351	$10,968,700
Total cost per ton of collected trash		$55.53		$73.33

eight years, and an interest rate of 9%, annual capital costs for the initial eight years of intensive recycling is estimated at $1,194,870. An additional $342,000 is spent each year in order to allow for increased flexibility in setting up an annual truck purchasing schedule. Thus, the annual total capital costs for the first eight years of operations are estimated at $1,536,871, or $10.27 per ton of waste collected (see Table XXI). After the first eight years, ongoing annual capital outlays will be as shown in Table XVIII.

The total annual collection costs of the present and proposed systems are compared in Table XXI. Because of the initial one-time capital costs, during the first eight years the intensive recycling system's collection costs are about 41% higher than the current system's collection costs. After that time, the intensive recycling system's collection costs fall to a figure that is about 31% above the present system's cost of collection.

C. Processing Costs:

Once trash is collected -- whether unseparated or as household-separated fractions -- it is processed in ways that lead to final disposal. In the case of the present City system, this step begins with delivery of the collected, unseparated trash to transfer stations. Thereafter it is handled by BFI; about 10% is disposed of in landfills, and about 90% is taken to the Occidental incinerator. There certain ferrous, non-combustible components are removed and recycled; about 75% of the trash (by weight) is consumed by combustion, and the remaining 25% (ash) is landfilled.

The proposed intensive recycling system is designed to produce four trash streams of separated materials. One of these is

Table XXI

TOTAL ANNUAL COLLECTION COSTS

	Present System	Intensive Recycling System	Intensive Recycling System (First Eight Years)
Annualized capital costs	$ 550,000	$ 571,300	$ 1,536,871
Annual personnel costs	$8,306,500	$10,968,700	$ 9,721,647
Annual operating costs	$ 778,400	$ 1,046,500	$ 1,049,000
Total annual costs	$9,635,000	$12,586,600	$13,552,100
Annual cost per ton of trash collected:			
Capital	$ 3.68	$ 3.82	$10.27
Personnel	$55.53	$73.33	$73.33
Operating	$ 5.20	$ 7.00	$ 7.00
Total cost per ton of trash collected:	$64.42	$84.15	$90.60

Note: Capital costs for the first eight years of intensive recycling include the higher costs of converting from the present system to the intensive recycling system.

composted; two fractions are processed into recyclable products; the fourth fraction (non-recyclables) is landfilled. In practice, the fourth fraction will contain a small proportion of the total that is brought to the curb in an unseparated form, by households that fail to participate in the separation process. In computing processing costs, we shall assume 10% as a standard level of non-participation (i.e., a household participation rate of 90%). In addition, as indicated earlier, small proportions of the inputs to the composting and materials recovery processes are rejected and must also be landfilled.

The amounts of trash materials that are processed in these ways by both the present and the proposed systems are summarized in Table XXII. With this information in hand, it is then possible to estimate the cost of processing each of these streams, and hence from their sum, to compute the total processing cost for each of the two systems. These estimates are presented below.

1. Compost facility:

The specifications of a typical compost facility suitable for the proposed intensive recycling system are described in Section IV. Because the compostable, organic waste stream varies so much by season, the compost facility must be flexible in operating capacity. It is sized to accommodate the maximum capacity needed in the summer.

Capital costs for the facility are shown in Table XXIII. These are based on an estimate developed for CBNS by the manufacturer of a typical facility (BAV, Erlensee, West Germany). While the costs were computed for the United States, certain local costs had to be adjusted for the Buffalo area. Siting of the