california prison industry authority

State of California • Department of Corrections

ISSUES IN CRRF IMPLEMENTATION

CORRECTIONAL RESOURCE RECOVERY FACILITY INTERAGENCY PROJECT REPORT

MAY 20, 1994

Prison Industry Authority • City Of Folsom • California Integrated Waste Management Board • University Of California, Davis • Cal Poly, San Luis Opispo • California Resources • CH2M Hill

Prison Industry Authority • 560 East Natoma Street • Folsom , CA 95630-2200

TABLE OF CONTENTS

TABLE OF ILLUSTRATIONS

ACKNOWLEDGEMENTS

This report was produced under an interagency agreement involving several agencies contributing toward the pioneering efforts of the Correctional Resource Recovery Facility. Key staff with the state Prison Industry Authority were Larry Harrison, chief of PIA's waste management division and Karen Hall, implementation specialist with PIA. Key City of Folsom personnel include Bob Bailey, superintendent of solid waste, and recycling coordinators Kevin Miller and Michael Rock.

Staff of the California Integrated Waste Management Board involved with the interagency project included Francisco Gutterres and Pat Bennett. Byron Fitzgerald, advisor to Boardmember Paul Relis, provided support and assistance.

Other individuals involved in the interagency project and the success of the Folsom CRRF include Masoud Kayhanian and George Tchobanoglous of the University of California, Davis, civil engineering department.

This report was prepared by Kelly Smith of California Resources, a Sacramento-based consulting firm specializing in California waste management recycling policies and practices.

EXECUTIVE SUMMARY

Interagency agreement

This report is an element of the interagency project formed by agreement between the state Prison Industry Authority (PIA) and California Integrated Waste Management Board (CIWMB) to study and report the implementation of PIA's Folsom Correctional Resource Recovery Facility (CRRF).

The CRRF material recovery and composting operation utilizes state prison inmate labor to process the wastestream of local municipalities. The CRRF applies an unprecedented level of labor to the sorting process, separating the entire wastestream into distinct categories, including market "high-grading" into specific market grades.

Extensive separation, in turn, makes possible technologies such as anaerobic composting of separated organic wastestream fractions. Marketing of separated materials is the responsibility of participating CRRF municipalities, with PIA assistance in developing the market opportunities for CRRF recyclables.

CRRFs hold particular promise in rural and remote areas where prisons are often sited. PIA has special capabilities to assist local governments in achieving state waste diversion mandates, including statutory financing authority, suitable siting, preference as a vendor of products to public agencies, and access to the inmate labor force.

Ultimately, application of the Folsom experience will be available to California communities striving to reduce their disposed wastestream. Toward that end, the CIWMB has assisted in funding demonstration activities and facilities, research and special topic reports relating to the Folsom CRRF project, such as the following:

- "Issues in Anaerobic Digestion." A report on the efforts to implement municipal-scale, high-solids anaerobic composting at the Folsom site, including pilot study conducted by University of California, Davis, as well as design progress, material handling, operating and other related issues.

- Learning Center. The Folsom CRRF facility includes a dedicated room to provide seminars and other activities which will transfer the facility's technologies while providing immediate access to observation of the technologies. The Learning Center is anticipated to be used by local government officials, waste management professionals, CIWMB staff and researchers.

- Demonstration projects. The CRRF facility is designed to incorporate the integrated approach to waste management set forth under AB 939, the state's Integrated Waste Management Act of 1989. As such, it will test unique, integrated source-separation activities and the facility's material handling approaches.

- Market development approaches. The facility is unique in the range of materials separated. PIA operates a variety of manufacturing enterprises and enjoys a special preference in marketing its products to state agencies. PIA is investigating secondary manufacturing utilizing materials separated from the wastestream.

This report, "Issues in CRRF Implementation," features the results of the Folsom project implementation and focuses on issues faced in realizing the potential of the CRRF concept. It includes extensive information and data on the CRRF's processing of representative municipal waste. It presents the extensive research data and design prepared for the unique composting aspect of the project. It analyzes the project from an integrated waste management approach, including demonstrations of tailored source-separation programs. Special focus was placed on the CRRF's ability to produce clean, homogenous organic feedstocks for the composting element.

Project summary

Implementation of the Folsom CRRF began in May of 1993, the result of several years of preparation. Preparation included siting, design, approvals and agreements between PIA and the City of Folsom, as well as extensive study by researchers with the University of California, Davis, California Polytechnical Institute and others.

The 15.5 acre project site adjacent to the state's Folsom prison (California State Prison, Sacramento) in the northeast corner of Sacramento County features a 37,000-square-foot material recovery building with ancillary operations such as organic material size reduction equipment and storage. Anaerobic composting vessels are expected to be constructed sometime in 1994. Meanwhile, the aerobic composting operations are being conducted.

The City of Folsom collects all City residential and commercial waste. PIA charges the City to separate City waste tipped at the facility. The waste is separated into different types of materials on the tipping floor, on a primary sorting line stationed with 18-20 inmates, and on a secondary sorting line attended by seven or eight inmates.

Sorted materials are baled and prepared for sale by the City of Folsom. Organic materials including separated yardwaste, nonrecyclable paper and food waste are prepared for composting at the site. The City is responsible for the marketing of all materials.

The 80-100 inmates working in the facility are from the City of Folsom Return to Custody (RTC) facility. The RTC is a City-owned, 400-bed facility housing state penal convicts under a for-profit agreement with the state Department of Corrections.

Folsom CRRF operations were authorized under a demonstration permit issued by the Local Enforcement Agency, the Sacramento County Department of Environmental Management. The permit allows the facility to operate conditionally while full solid waste facility permits await concurrence by the CIWMB.

Demonstration results

The demonstration period studied occurred during the spring of 1993. About 70 tons, slightly more residential than commercial waste, were closely analyzed during that period. At the same time, the City began conducting demonstration source separation programs, with the results carefully tracked.

PIA has continued to monitor operation results since the demonstration period. Initial operations and equipment shakedown occurred during and after the initial demonstration period. Throughput ability of the facility has increased significantly since the demonstration period: from 10 tons per day than 50 tons per day. However, the process performance, measured in percentages separated by type, has remained consistent.

The demonstration operations showed that the CRRF operations were able to separate more than half of the waste accepted into material types. About 30-40 percent of the total accepted was separated into marketable types. This did not include all organic materials in the mixed wastestream. About 10 percent or more of the total accepted was typically bagged yardwaste.

These process results validated the basic assumption of the CRRF concept: that a convict-labor-intensive operation could sort the entire municipal wastestream. The demonstration also gave PIA working experience in specific aspects such as security, material identification and workforce assignment. Further experience will benefit operations in improved separation efficiency, recyclables marketing, worker efficiency and organics recovery.

Issue results

Several key issues in CRRF implementation were analyzed in conjunction with this report. These are issues with important long-term implications to the success of the concept. Many of these issues relate to the anaerobic composting component of the program and CRRF ability to separate recyclables and compost feedstock. The issues considered relate to the unique features of the CRRF concept, many of which relate to the unprecedented level of convict labor applied to the wastestream.

The anaerobic composting operations is an example. It can capture useful gas byproducts, as well as humus; odors can be well controlled; a broader range of organics can be used as feedstock. A separated feedstock greatly enhances the anaerobic, in-vessel composting technology. Clean food, paper and yardwaste feedstock is anticipated with the CRRF labor available to separate the municipal wastestream. The "high-solids" anaerobic composting operation planned by PIA at the Folsom site demonstrates an approach to meet and exceed the 50 percent landfill diversion goal set in California's Integrated Waste Management Act.

Following are the four special issues addressed by this report:

Vessel design

PIA has designed a vessel to conduct municipal-scale, anaerobic digestion of organics derived from municipal solid waste. The design is presented in this report. Many unique engineering applications are featured in areas such as material loading, humus output, sabotage-safe instrumentation and simple temperature control.

Researchers George Tchobanoglous and Masoud Kayhanian from the University of California, Davis civil and environmental engineering department helped prepare composting technology for PIA. Many of their results are included throughout this report. Preliminary vessel design was performed for PIA by Doug Williams of the California Polytechnical, San Luis Obispo, mechanical engineering department. Final construction design was completed by the engineering consulting firm CH2M Hill.

Humus characteristics and end-use implications

An important element of the CRRF composting operation will be the nature of its humus byproduct. The issues associated with its end applications and markets are similar to that of compost. However, the CRRF humus will have unique characteristics, resulting from its feedstock and process, which could be important to its end use, including nutrients, water content and other constituents.

UCD engineering researchers thoroughly analyzed representative samples of the expected CRRF humus. Test results presented include humus characteristics such as moisture content, nutrients, appearance and other factors. The results indicate that the humus is well below threshold levels for heavy metal constituents. The humus has no detectable odor and small particle size.

The UCD researchers found some humus phytotoxicity. Phytotoxicity is toxicity to plant growth. Reasons for the phytotoxicity were not known. Recommendations to adjust for phytotoxicity in end-use are presented.

Source separation demonstrations

The City of Folsom evaluated the Folsom CRRF through demonstration of several unique source separation programs, specially designed to maximize CRRF recovery.

CRRF potential depends on the unprecedented labor used to sort the municipal wastestream. However, PIA recognizes certain limitations on recyclables' sales quality due to sorting from the mixed wastestream. It realizes the need for the CRRF operation to be an integral complement to integrated municipal waste management.

Source separation was also evaluated for improved CRRF operations. Maximized levels of source-separated materials handled by the CRRF may improve facility throughput. Potentially even more important may be source separation of organics such as food and yardwaste. Source-separated organics can contribute a clean feedstock to the anaerobic digestion operations.

The City of Folsom designed source separation programs to co-collect bagged recyclables, including yardwaste, from City residences; to collected wet and dry separated recyclables from businesses and to further seek separated yardwaste from special generators such as landscapers and spring cleaning season.

The demonstrations conducted by the City were evaluated by project specialists from the CRRF facility and the City. They developed recommendations for optimum CRRF "front-end," source separation programs. The demonstration phase indicates that source-separated yardwaste and newspaper, in particular, could immensely improve the over-all efficiency and operations of an integrated CRRF program.

Permitting and regulatory issues

Several challenging issues in permitting and regulation arise because of unique features of the CRRF concept: particularly the composting element. For example, the composting process is different from the typical composting operation. The CRRF digestion process produces both energy (gas) and a humus byproduct. It uses materials separated from waste at the facility, as well as been source-separated materials.

Permitting and regulatory coordination of the Folsom CRRF was conducted by California Resources, a Sacramento-based consulting firm specializing in California waste policies and practices. The firm prepared submission of separate solid waste facility permits for both the material recovery facility and composting facility, as required by current regulations. California Resources also obtained a special demonstration permit exemption for the operations which allowed the CRRF to begin commission under conditional status.

The report on the issues of permitting and regulation prepared by California Resources includes a review of the solid waste facility permit and its relevance to the CRRF concept. Also presented are issues associated with solid waste facility permitting of composting facilities and their relevance to the CRRF anaerobic digestion operations. The report features recent federal and state performance standards being applied to compost end products.

The permitting and regulatory issues report also details the facility's acquisition of the demonstration permit. The regulatory review of start-up operations under the demonstration permit included regular inspections and reporting. The report cites the demonstration permit as a potentially valuable mechanism to allow Local Enforcement Agencies to observe and become familiar with the new generation of material recovery and composting facilities as they operate under site-specific, conditional status.

High solids anaerobic composting operations guide

California communities seeking to meet 50 percent waste diversion goals may consider the CRRF concept in conjunction with high-solids anaerobic composting. An advantage of anaerobic composting technology is PIA's "low-tech" emphasis on design, construction and operation.

A guide to operate PIA's anaerobic composting technology was produced by University of California, Davis researchers who conducted pilot operations of the technology. The guide identifies the key issues associated with operating high-solids anaerobic composting. A battery of analytical techniques is offered. Simple problem identification and response approaches are presented.

PROJECT DESCRIPTION

Site description

The Folsom Correctional Resource Recovery Facility (CRRF) is located on California state property adjacent to Folsom State Prison. An aerial view of the site is shown in Illustration 1. The prison is located within boundaries of the City of Folsom, as it has been for more than 100 years. The City of Folsom is located in the far northeast corner of the County of Sacramento.

The total CRRF facility-- material recovery and composting-- occupies roughly 15.5 acres at the north side of the 1,200 acres of state property occupied primarily by the California Department of Corrections. The material recovery facility occupies 37,500 square feet on the site.

The facility is located very near other prison-related uses. The Return-to-Custody Facility (RTC), from which the facility workforce comes each day, is approximately 400 yards to the east of the CRRF site. The administrative offices of Prison Industry Authority are located approximately 500 yards from the CRRF to the southeast.

Access is from the prison service road extending to Natoma Street. The service road leads from Natoma Street between the RTC facility and the PIA offices to the eastern side of the site. There vehicles enter the site through a scale and sally port to deliver loads to the facility.

Composting site

Composting operations occupy 8.6 acres of the total 15.5-acre project site. The composting takes place on the northern area of the site, with composting vessels at the far northern perimeter and two acres of drying beds in between composting and material recovery operations.

The composting vessels are located in an abandoned manmade reservoir. The reservoir, which is not covered, is formed by earthen embankments approximately 25 feet high. A dirt road leading to the reservoir branches into two roads, one that leads into the reservoir and one that curves along the top of the southern and western sides of the reservoir. The abandoned water reservoir will serve as a containment feature in the event of ruptures of any types which release materials from the vessels.

ILLUSTRATION 1

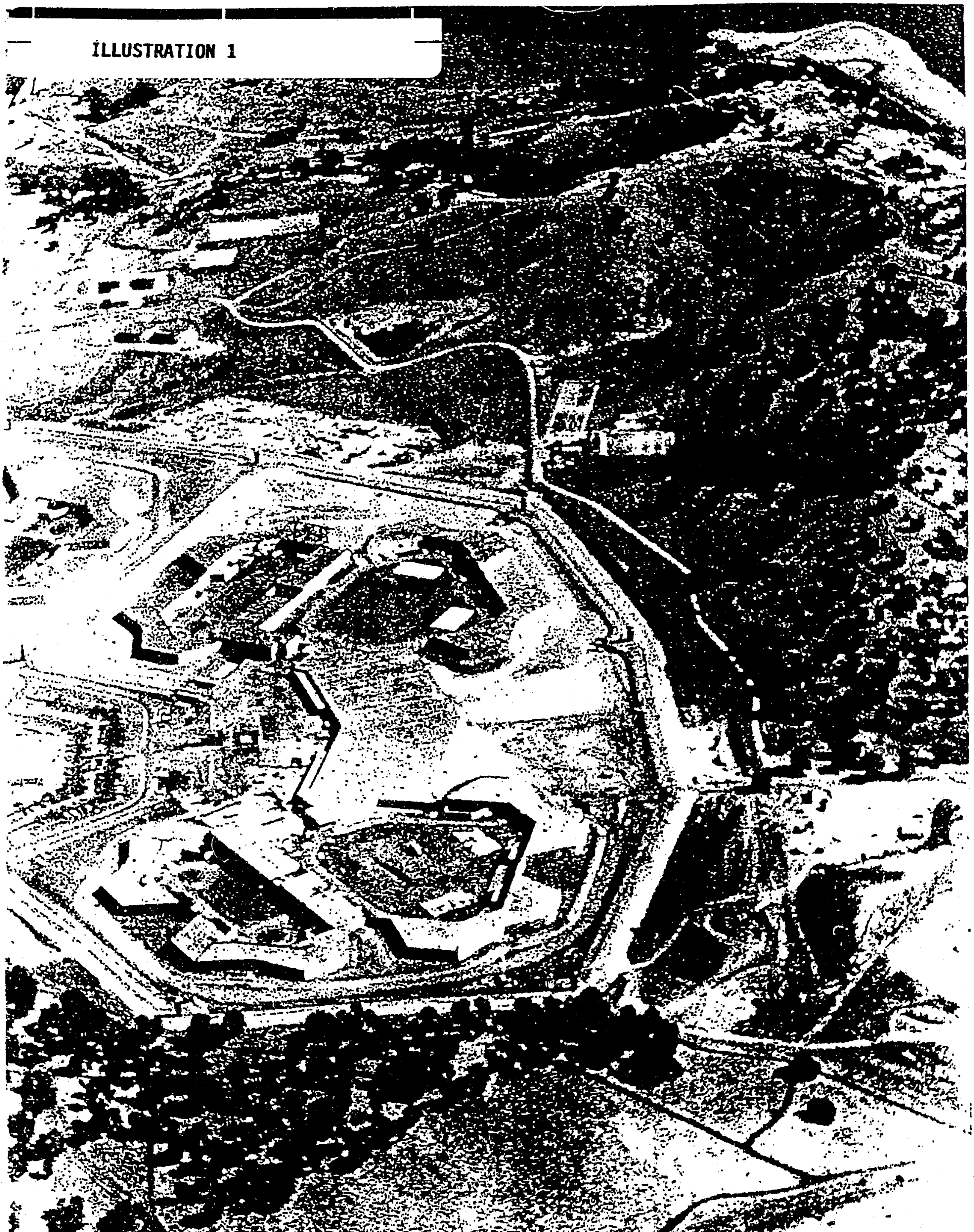


Illustration 1: Aerial View of the Site

Illustration 2: Site Location

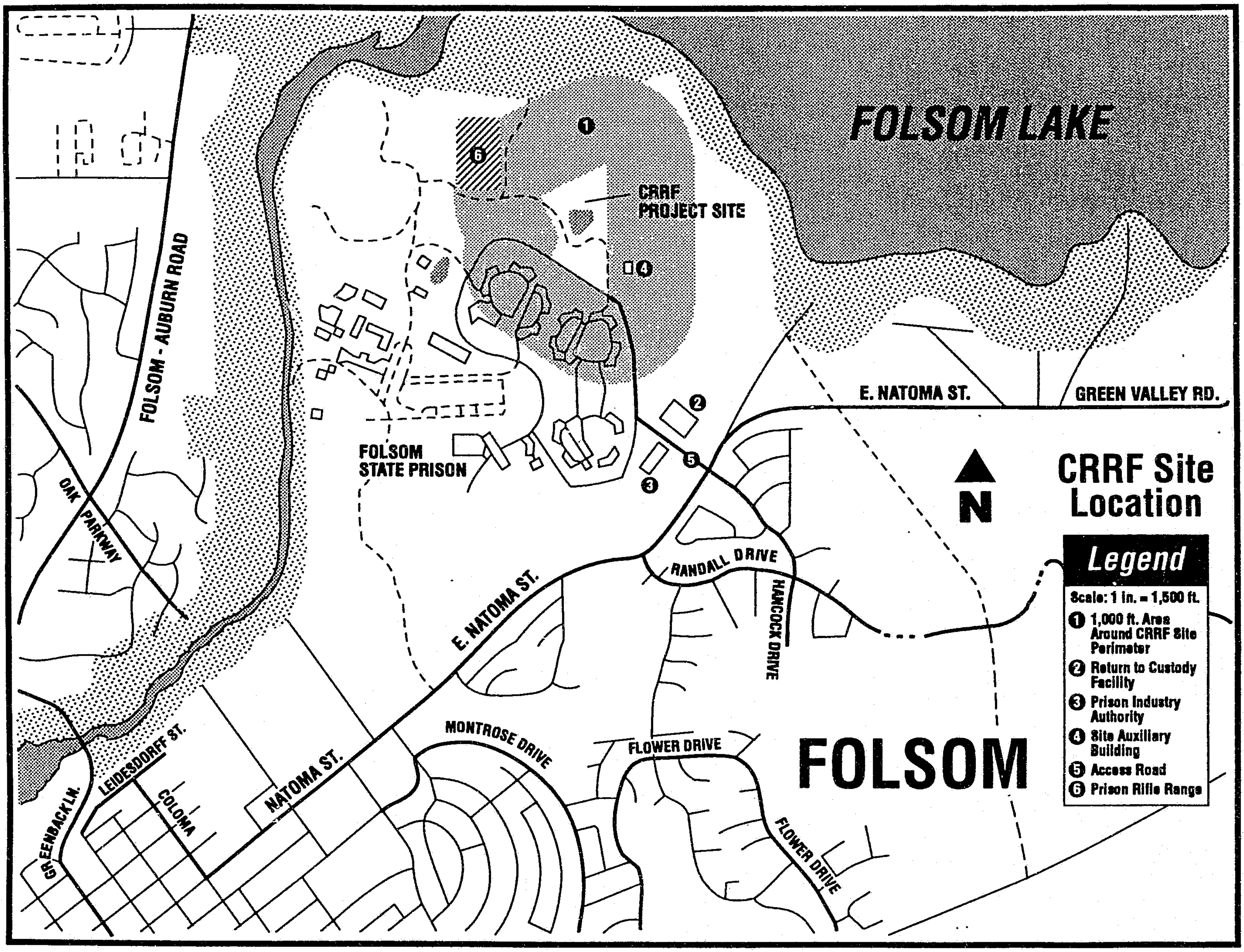
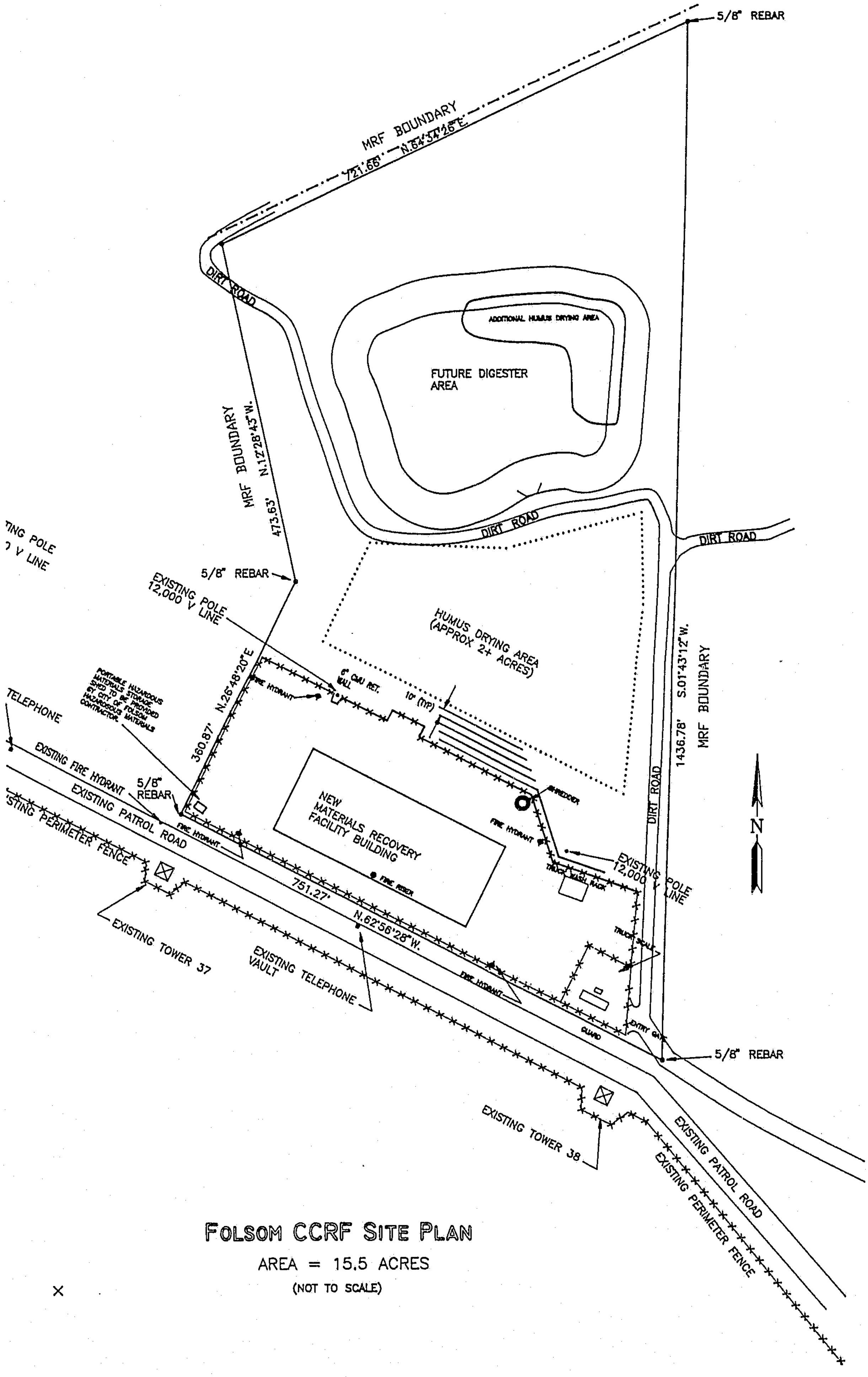

FOLSOM LAKE
CRRF PROJECT SITE
FOLSOM STATE PRISON
FOLSOM - AUBURN ROAD
OAK PARKWAY
E. NATOMA ST.
GREEN VALLEY RD.
RANDALL DRIVE
HANCOCK DRIVE
MONTROSE DRIVE
FLOWER DRIVE
NATOMA ST.
LEIDESDORFF ST.
COLOMA
GREENBACK LN.
FOLSOM
N
CRRF Site Location
Legend
Scale: 1 in. = 1,500 ft.
1 1,000 ft. Area Around CRRF Site Perimeter
2 Return to Custody Facility
3 Prison Industry Authority
4 Site Auxiliary Building
5 Access Road
6 Prison Rifle Range

Illustration 3: Site Plan



Folsom CCRF Site Plan

AREA = 15.5 ACRES

(NOT TO SCALE)

Recovery facility operations and design

The PIA recovery facility has been designed to accept from 100 tons per eight-hour shift to a maximum 300 tons per day of municipal waste materials. Materials accepted at the facility are dumped on a tipping floor, presorted, then conveyed up to and along an elevated sorting line worked by RTC inmates.

Through unprecedented levels of labor application and extensive primary and secondary sorting, the facility is designed to divert the majority of entering materials for recycling, composting or other alternative end-uses.

Significant volumes of organic material sorted from the line and from presorting are directed to the composting operations associated with the facility. These organic fractions include food, wood and yard waste and nonrecyclable papers. It is anticipated that a minimum of 50 percent of the material accepted at the facility will be composted there.

Materials recovered for recycling are baled and otherwise processed as appropriate for marketing. Material unable to be diverted is transported for disposal by the City of Folsom. Operations are conducted by City of Folsom and Prison Industry Authority personnel supervising inmates from the City of Folsom Return to Custody Facility.

Facility design and operations

The CRRF material recovery facility is 300-feet long by 125-feet wide. Utility rooms for employee changing, mechanical, administrative and office space and a large learning area account for approximately 25 feet along the southern side of the building, accessible to the tipping floor.

The 37,500-square-foot pre-fabricated metal building features a gabled metal roof, low profile, clear-span, frame structure with straight, sidewall columns. The roof slope is one inch per foot. All structural steel sections and welded plate members are designed according to the specifications of the American Institute of Steel Construction (AISC).

The facility features three 20-foot-wide doors on the east wall. These doors provide vehicle access to the tipping floor. Materials are sorted along two picking and processing lines running along both sides of the building.

Organic materials destined for the CRRF composting operation are recovered from the tipping floor and the picking lines. Processed materials ready for market are moved out the west side of the building through a 20-foot-wide door centered there. Residue to be landfilled is moved out this door to transfer containers.

Source separation

The PIA recovery facility is a key feature of City of Folsom strategies to meet state mandates to cut in half, by the turn of the century, the waste it disposes in landfill. In addition, the City has adopted an aggressive approach to source separation and source reduction of generated waste materials. These programs have been integrally designed with the operation of the recovery facility to maximize material quality. Demonstration of these programs is addressed in the discussion of *Issues in CRRF Implementation.*

Facility operations

The unloading "tipping floor" of the facility measures 100-by-100 feet at the east entrance end of the facility. Vehicles enter through three 16-feet-high by 20-feet-wide doors into the tipping and presort area. After tipping floor inspection, materials are pushed onto in-floor hoppers and conveyed up to the second level in the main sorting area where primary sorting occurs.

When the facility is fully operational, approximately 15 truckloads per shift will be transported to the CRRF via an access road off East Natoma Street in Folsom. Once a truck-load is collected and transported to the CRRF, the load is tipped on the facility's presorting floor. It then returns to its route.

At the sally-port entrance to the facility, full waste vehicles are weighed to assess the tipping fee and then proceed to the enclosed receiving area. The MSW is then unloaded onto the tipping floor. Here the waste is spread over the presort area and visually inspected. At this point, oversized, bulky items such as tires, carpet rolls and white goods are removed and taken for further processing.

Any organic materials such as yardwaste which have been brought clean and source-separated may be removed in the presort phase and taken directly to the shredding and composting operations. Items identified as hazardous material are immediately removed wherever they are found in the CRRF process. The hazardous material is collected for disposal by a licensed hazardous waste hauler.

Primary sorting takes place next. Material is conveyed to an elevated picking line attended by prison inmates. The inmates then pick and sort the materials into general types, such as newspaper, mixed paper, plastics, glass (by color), metals, and aluminum cans.

Waste processing

Sorting of materials occurs largely within the 100-feet by 200-feet area to the west of the tipping floor. Materials are conveyed upward eight feet from the tipping floor area to the processing area through a four-by-four-foot opening at the height of the sorting line. The two pre-manufactured primary sorting lines are 30-inches wide, 66-feet long. Each features stations for 15 pickers of various materials.

Chutes opposite the pickers drop materials into collecting containers on the floor level of the processing room. Recyclable materials sorted by the primary process are then taken to secondary picking lines for separation into market categories such newsprint, white paper or mixed paper, or to be baled or otherwise processed for market.

Secondary sorting of materials such as mixed plastics and paper takes place on two, 24-foot-long secondary sorting lines, each featuring seven picking stations. The sorting lines are located 10 feet from the walls of the facility. The corridor between the sorting lines is 50 feet wide along the 200 feet of the processing area, adequate for maneuvering of vehicles. Balers are located at the end of each sorting line.

The primary storage of sorted recyclable nonorganics takes place in four-yard bins located at floor level under each sorting line. Storage areas are available along the walls of the east end of the sorting and processing area. Baled recyclable materials are stored for short periods within the walls of the facility before being moved by special purpose forklift to containers outside the facility. These containers vary in size and structure according to what is provided by the buyers of the recyclable goods.

Compaction of recyclable materials is conducted by a baler. Recyclable materials sorted by the primary sorting line are then taken to secondary picking lines for separation into market categories such as newsprint, white paper or mixed paper. Recyclable materials are then baled or further prepared for marketing. The organic fraction of the wastestream which is not otherwise diverted is then taken using four-yard containers, to the preprocessing area of the composting process.

Residue to be landfilled is moved from the tipping floor area, or as residue after processing. The residue is moved in the corridor between the picking lines. The material is then loaded directly into City vehicles for transport to landfill.

Composting process

The total initial capacity of the composting system at the PIA Folsom CRRF will be 293,760 cubic feet, which is approximately 2,973 tons of material. Much of this volume will be water. Adjusting for the water, this capacity is adequate for approximately 78 tons of organic material per day. Roughly 28 days are required to anaerobically digest the organic material.

The initial capacity will readily process the 50-60 tons of organic waste expected from the City of Folsom wastestream. Composting capacity will increase to a total of three digesters capable of handling the organic fraction of the maximum wastestream of 300 tons per day for which the CRRF facility is designed.

The organic materials from CRRF sorting are pre-processed through a shredding and pulverizing system for size reduction, transported to the adjacent composting area in enclosed mixing trailers and loaded into fully contained composting vessels. After being digested, the humus is dried in covered drying beds and gathered for storage and marketing.

Preprocessing

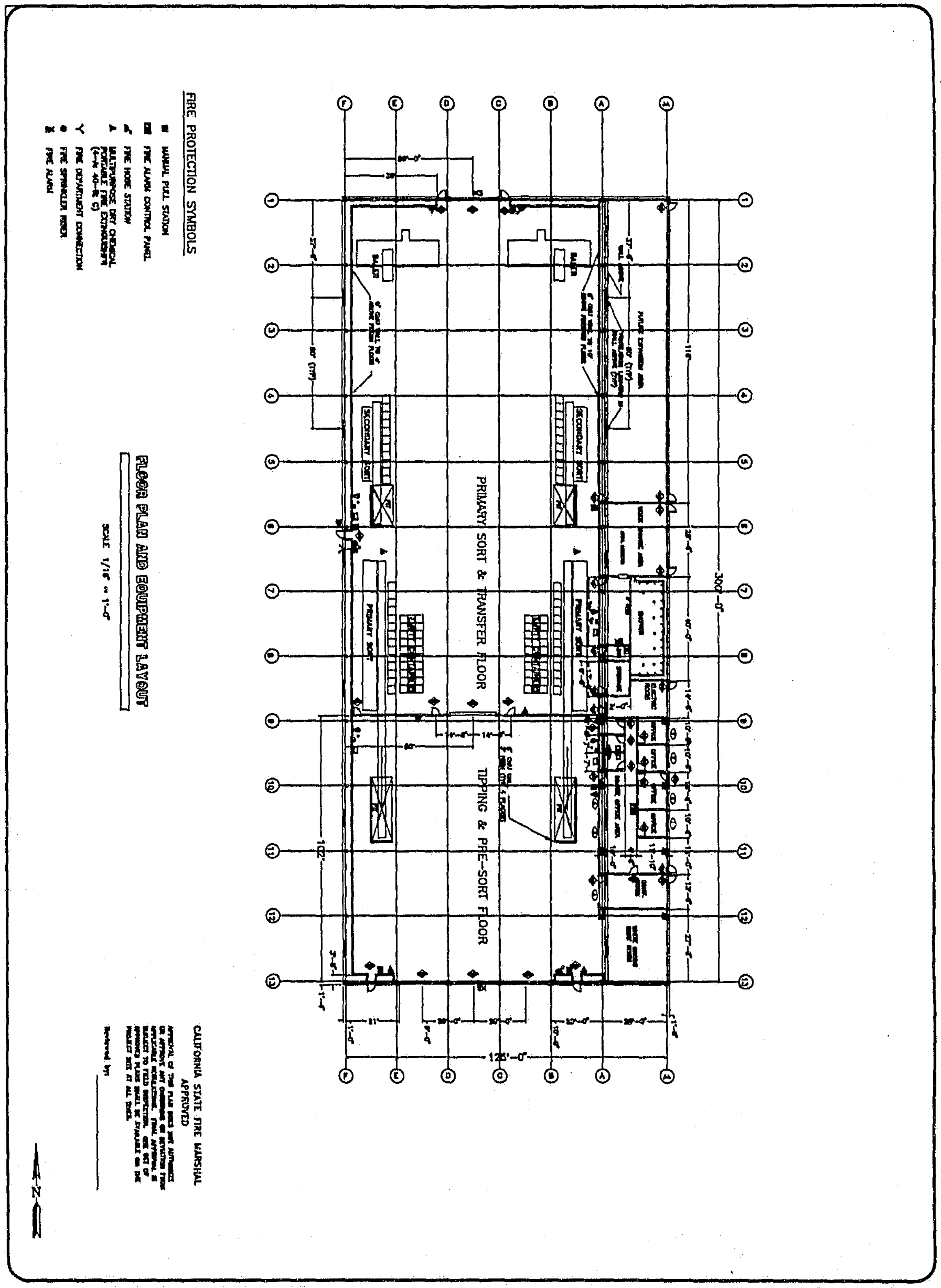
Shredding of the organic materials is conducted using a two-stage shredding and grinding system to specifications necessary to prepare organic materials for composting. All particle reduction is done outside of the materials recovery building on the north side of the building.

The shredding and grinding system reduces materials to at least 3/4-inch size. The system has a throughput capacity of 20 tons per hour. System enclosures are designed to resist fires and explosions, and to minimize noise generated by the shredders. Output of the finished pulverized material is elevated 15 feet and discharged directly into mixing trailers driven beneath. The covered trailers used to transport the organic solids feature mixing augers.

Digester vessels

Materials will be delivered to receiving station at the digestion vessels. The receiving station consists of an unloading area and digester feed hopper. The digester feed hopper contains one screw-conveyor to feed the waste material into the digester.

Illustration 4. Facility process flow



PIA

PRE ENGINEERED METAL BUILDING

CALIFORNIA DEPARTMENT OF CORRECTIONS
PRISON INDUSTRY AUTHORITY / CITY OF FOLSOM

MATERIALS RECOVERY FACILITY

DRAWING A-1

Prison Industry Authority
Implementation Division
Engineering Department
560 E. Natoma
Folsom, California
95630-2200

Larry L. Harrison, Chief
Industry Implementation

Dilution water is provided to the vessels from a separate 30,000-gallon holding tank near the material recovery building. The tank collects waste, "gray water" from both the Return-to-Custody facility and the material recovery building. The water is pumped from the holding tank to the digester vessels.
Plans provide for three to contiguous composting vessels suitable for either aerobic or anaerobic composting. Each digester will be 32 feet wide and 120 feet long and 22 feet high; a total volume of 84,480 cubic feet for each digester.

The vessels feature a gas recovery system, instrumentation, sampling wells, valves, a gas flaring system and condensate traps. Digested material is removed from the vessels using a pump. The discharge piping includes provisions to recycle digester contents to the front end of the digester.

Anaerobic composting

The CRRF composting operation will be capable of utilizing either aerobic or anaerobic processes. However, the anaerobic process will be the preferred manner of composting due to the production methane. When using anaerobic process, the composting vessels, also referred to as "digesters," are covered during all times material is being composted. Automatic paddle mixers aid mixing of organic material inside the vessels. Material will be retained in the vessels for a minimum of 28 days.

PIA's anaerobic digestion process provides for volumetric reduction of organic matter while producing biogas (composed of methane and carbon dioxide) and organic humus through the biochemical activity in a sealed, oxygen-free environment. It differs from other anaerobic processes, such as the low-solid method used in sewage treatment.

The residue from the anaerobic composting process is a humus-like material. Using the thermophilic system (above 130 degrees Fahrenheit) proposed for this project, all pathogens and most of the odors will be destroyed. Temperature will be maintained by a heating system which will inject steam in the digester vessels. The boiler heating system can utilize both biogas captured from the vessel and natural gas.

After removal from the anaerobic vessels, additional aerobic composting will dry and further decompose the anaerobic digestate, resulting in a humus that is very similar in texture and appearance to clean dirt. Enclosed aerobic vessels will eliminate run-off or leachate problems. To minimize odors from the composted material, air from the vessels will be collected by a fan and passed through a soils filter before being ventilated.

After being dried, the material will be screened to remove any oversized or undesirable materials prior to packaging and marketing as a soil amendment for uses such as wetlands reclamation, turf farming, or horticulture.

Monitoring, testing and modifications

Once the composting process is in operation, each digester vessel will be tested daily to assure proper functions by criteria such as the carbon-to-nitrogen ratio, temperature, pH level, organic matter stabilization, gas composition, gas volume, ammonia, alkalinity and coliforms.

PIA will also regularly monitor and test gas and humus produced by the aerobic composting operation. Where necessary, modifications will be made in various functions, such as material handling, fluid levels, nutrient adjustment and heating to assure optimum operations and products.

Water use

The composting process requires a maximum of 30,000 gallons of water to process the of organic materials. Only water removed with digestate will need replacing. Waste "gray water" from the RTC facility may be used as replacement water after proper treatment.

Description of wastes

The wastes to be accepted represent almost the entire generated City of Folsom wastestream. This wastestream was detailed in the Waste Generation Study developed for the City of Folsom's Source Reduction and Recycling Element. Highlights of the relevant findings of the Waste Generation Study are presented here.

The study includes a preliminary characterization of the waste disposed by Folsom from residential, commercial and other (primarily prison and park) generators. This characterization data was produced during two sorts of Folsom waste conducted in the winter and summer seasons.

The 1990 City characterization study followed the Klee and Carruth sampling methodology. The following tables represent the two seasonal characteristics of the City of Folsom's wastestream, as well as the annual aggregate wastestream composition.

Table 1.

CITY OF FOLSOM
AGGREGATE WASTE CHARACTERIZATION
Winter Season/All Generators
Sample Size: 11535.0 Mean Sample Size: 274.6

Materials Type	Pounds	Mean	Percent
1. Paper	5217.0	124.21	45.23%
a. Corrugated	1524.6	36.30	13.22%
b. Mixed Paper	743.8	17.71	6.45%
c. Newspaper	803.2	19.12	6.96%
d. High-grade ledger	206.1	4.91	1.79%
e. Other paper	1939.3	46.17	16.81%
2. Plastics	1053.8	25.09	9.14%
a. HDPE containers	119.4	2.84	1.04%
b. PET containers	15.6	.37	.14%
c. Film plastics	474.3	11.29	4.11%
d. Other plastics	444.5	10.58	3.85%
3. Glass	398.4	9.49	3.45%
a. Refillable bev.	.0	.00	
b. CRV glass	104.3	2.48	.90%
c. Other recycl.	273.4	6.51	2.37%
d. Other nonrecyc.	20.7	.49	.18%
4. Metals	474.6	11.30	4.11%
a. Aluminum cans	58.7	1.40	.51%
b. Bimetal containers	.0	.00	
c. Ferrous, cans	221.0	5.26	1.92%
d. Nonferrous	34.2	.81	.30%
e. White goods	32.6	.78	.28%
f. Other metals	128.1	3.05	1.11%
5. Yard waste	2152.5	51.25	18.66%
6. Other organics	1740.3	41.44	15.09%
a. Food waste	1275.9	30.38	11.06%
b. Tires and rubber	51.2	1.22	.44%
c. Wood waste	169.1	4.03	1.47%
d. Agr. crop res.	.0	.00	
e. Manure	.0	.00	
f. Textiles, leather	231.0	5.50	2.00%
g. Other organics	13.1	.31	.11%
7. Other wastes	498.4	11.87	4.32%
a. Inert solids	369.5	8.80	3.20%
b. HHW and containers	128.9	3.07	1.12%

Table 2.

CITY OF FOLSOM
AGGREGATE WASTE CHARACTERIZATION
Summer Season/All Generators
Sample Size: 12165.5 Mean Sample Size: 276.5

Materials Type	Pounds	Mean	Percent
1. Paper	4878.7	110.9	40.1%
a. Corrugated	1854.2	42.1	15.2%
b. Mixed Paper	481.0	10.9	4.0%
c. Newspaper	609.7	13.9	5.0%
d. High-grade ledger	162.4	3.7	1.3%
e. Other paper	1485.5	33.8	12.2%
d. Diapers	285.9	6.5	2.4%
2. Plastics	991.7	22.5	8.2%
a. HDPE containers	63.2	1.4	.5%
b. PET containers	16.1	.4	.1%
c. Film plastics	568.4	12.9	4.7%
d. Other plastics	344.0	7.8	2.8%
3. Glass	304.1	6.9	2.5%
a. Refillable bev.	.0	.0	.0%
b. CRV glass	137.9	3.1	1.1%
c. Other recycl.	160.4	3.6	1.3%
d. Other nonrecyc.	5.8	.1	.0%
4. Metals	374.1	8.5	3.1%
a. Aluminum cans	37.7	.9	.3%
b. Bimetal containers	.5	.0	.0%
c. Ferrous, cans	172.8	3.9	1.4%
d. Nonferrous	20.9	.5	.2%
e. White goods	.0	.0	.0%
f. Other metals	142.2	3.2	1.2%
5. Yard waste	2919.4	66.4	24.0%
6. Other organics	2202.7	50.1	18.1%
a. Food waste	1642.8	37.3	13.5%
b. Tires and rubber	29.4	.7	.2%
c. Wood waste	239.9	5.5	2.0%
d. Agr. crop residue	.0	.0	.0%
e. Manure	4.2	.1	.0%
f. Textiles, leather	222.4	5.1	1.8%
g. Other organics	72.3	1.6	.6%
7. Other wastes	494.8	11.2	4.1%
a. Inert solids	366.8	8.3	3.0%
b. HHW and containers	128.0	2.9	1.1%

Table 3.

CITY OF FOLSOM
AGGREGATE WASTE CHARACTERIZATION
Annual/All Generators
Sample Size: 23700.5 Mean Sample Size: 275.6

Materials Type	Pounds	Mean	Percent
1. Paper	9809.8	114.07	41.39%
a. Corrugated	3378.8	39.29	14.26%
b. Mixed Paper	1224.8	14.24	5.17%
c. Newspaper	1412.9	16.43	5.96%
d. High-grade ledger	368.5	4.28	1.55%
e. Other paper	3424.8	39.82	14.45%
2. Plastics	2042.5	23.75	8.62%
a. HDPE containers	182.6	2.12	.77%
b. PET containers	28.7	.33	.12%
c. Film plastics	1042.7	12.12	4.40%
d. Other plastics	788.5	9.17	3.33%
3. Glass	702.5	8.17	2.96%
a. Refillable bev.	.0	.00	
b. CRV glass	242.2	2.82	1.02%
c. Other recycl.	433.8	5.04	1.83%
d. Other nonrecyc.	26.5	.31	.11%
4. Metals	848.7	9.87	3.58%
a. Aluminum cans	96.4	1.12	.41%
b. Bimetal containers	.5	.01	
c. Ferrous, cans	393.8	4.58	1.66%
d. Nonferrous	55.1	.64	.23%
e. White goods	32.6	.38	.14%
f. Other metals	270.3	3.14	1.14%
5. Yard waste	5071.9	58.98	21.40%
6. Other organics	3951.3	45.95	16.67%
a. Food waste	2918.7	33.94	12.31%
b. Tires and rubber	80.6	.94	.34%
c. Wood waste	409.0	4.76	1.73%
d. Agr. crop residue	.0	.00	
e. Manure	4.2	.05	.02%
f. Textiles, leather	453.4	5.27	1.91%
g. Other organics	85.4	.99	.36%
7. Other wastes	993.2	11.55	4.19%
a. Inert solids	736.3	8.56	3.11%
b. HHW and containers	256.9	2.99	1.08%

CRRF DEMONSTRATION RESULTS

Background

Operation of the Folsom Correctional Resource Recovery Facility began in April, 1993, when the facility received a solid waste facility demonstration permit from the Local Enforcement Agency. The demonstration permit allowed the facility to begin accepting solid waste from the City of Folsom for processing into recyclables, pending approval of the full state solid waste facility permit.

The demonstration permit allowed the CRRF to eventually accept up to 100 tons per day, after demonstrating proper operations beginning with a daily limit of 10 tons per day . The City of Folsom began tipping two truck loads a day, beginning with one day per week. During the spring and summer of 1993, operations gradually increased to a daily 30 tons, five days a week.

During this period, the facility was studied for its ability to process materials. Careful records were kept of the facility's different processes using material accounting. Material accounting tracks materials, by types and quantities, from the tipping floor as they are processed out of the facility in the form of recyclables, residue, compostables or other final paths.

This analysis of the CRRF operations provides information useful for many purposes: quantities and qualities of recyclables, and their value, can be projected; the impact of "front-end" programs such as the City's source separation activities can be assessed; operations such as the sorting process can be evaluated. The analysis also provides basic information on the performance of the process, such as the quantities being diverted from landfill.

To obtain the information, a digest of each day's waste was recorded. The digest included information on the source of the waste by generator (residential, commercial) and route, the total weight accepted in the load tipped, time taken to process the material, and weight of types of material at each process in the CRRF operations.

The total amount of waste analyzed during the demonstration analysis was 72.7 tons. It is important to note that the demonstration operations did not include composting, which will take place during a later demonstration. Materials destined for composting were carefully studied, however, as their quality and quantity will be important for CRRF composting.

Baseline characterization, demographics and other information was taken for the demonstration route established by the City of Folsom. The 325-home route was used for demonstrating residential source-separation.

Summary

The analysis of CRRF demonstration activities revealed that approximately 40 percent of waste accepted was processed into recyclable materials. This includes yardwaste separated on the tipping floor and some bulky items which were landfilled during the demonstration phase. Composting was not conducted during the demonstration.

Different types of waste were handled during the CRRF demonstration. This provided experience in the variety of loads generated by different sources. Commercial loads with a high percentage of cardboard can yield high diversion levels; residential loads with a high percentage of compostable grass clippings yield lower diversion.

It is important to note that demonstration analysis took place as the CRRF was going through initial operations. Equipment, personnel practices and operational methods were being put into place for the first time. Facility throughput initially was little better than three tons per hour, equipment downtime was frequent, floor operations chaotic. By the end of the summer, throughput was approaching seven tons per hour, equipment downtime was minimal and floor operations were well coordinated.

Operational adjustments made during the demonstration period did not appear to greatly impact analysis results. From the beginning to the end of the demonstration, quantities and types of materials handled at the different processes remained fairly consistent.

The demonstration operations featured only one of the two processing lines. Based upon the throughput of the one line, the facility will be capable of handling the designed 100 tons per shift with the addition of the second line. This will allow the facility to accept all of the waste currently generated by the City of Folsom.

The following table summarizes the material accounting for the demonstration period analyzed. Following the table are characterizations of the processes by generator type, first residential and then commercial. An explanation of the material accounting analysis precedes the characterization tables. Supplementary information on the CRRF operation and methodologies follows the characterizations.

Table 4.

OPERATIONS LOG

OPERATION	RESIDENTIAL TONS	COMMERCIAL TONS	TOTAL PERCENT
a. Presort	6.5	7.2	19
b. Primary	7.5	6.6	19
c. Second primary	2	0	3
d. Total diversion	16	13.8	41
e. Residue	24	18.9	59
f. Total*	40	32.7	100

* d+e

PROCESS CHARACTERIZATION REPORT

The figures given in the attached characterization forms were collected from weights taken on scales at the CRRF site. All containers at the facility are stenciled with a identification number and tare weight. The data is collected at the following locations in the plant process:

1. Tipping floor. This includes all material pulled from the tipping floor. The "other other" category is used in this form for bulky items removed on the tip floor.

2. The primary sort. This is the material remaining after a pre-sort on the tipping floor. This material goes up the conveyor to the picking stations in a continuous feed.

3. The secondary sort. For the purposes of these demonstration characterizations, this process can mean either of two things, which will be noted on the form:

   - A *secondary sort* of the materials picked from the primary line. These materials are separated further into subcategories of the materials;

   - A *second primary sort* of the materials left after the primary line. These materials may be represented in the same categories picked during the primary sort.

   The important distinction is that the second primary sort separates materials a second time according to the primary sort categories. The secondary sort further separates materials already picked on the primary line.

4. Residuals sort. This sort is derived from characterization of a representative sample, typically 600 or more pounds. This is material remaining after primary sort. The samples pulled from this end of the primary sort line are picked by inmates into categories. The percentages arrived at are applied to the total residual quantity for tonnages by type.

   Because sampled material has been processed extensively by this point, some visual accounting of types in the sorted categories was necessary. For example, estimates of the type of paper grades was made on survey of the paper pile after news and kraft had been separated from them.

The percentages given with the forms are percentages of pounds recovered by that process. When a full accounting of the tipped tonnage can be accounted through all of the above operations, it is possible to produce a characterization of the entire tonnage accepted. In those instances, this was provided with the daily digest and characterizations.

Table 5.

GENERATOR: RESIDENTIAL WASTE **PATH:** Tipping floor

TOTAL POUNDS: 13,832 **DATE:** May-June 1993

TIPPING FLOOR DIVERSION

Material	Percent	Pounds	Material	Percent	Pounds
1. Paper	23	2902	**4. Metals**	3	289
a. Corrugated	7	928	a. Aluminum cans	0.5	19
b. Mixed paper	14	1785	b. Bimetal containers		
c. Newspaper	2	189	c. Ferrous, cans	0.5	79
d. High-grade ledger			d. Nonferrous		
e. Other paper			e. White goods		
			f. Other metals	2	191
2. Plastics	4	378			
a. HDPE containers	0.5	20	**5. Yard Waste**	45	5920
b. PET containers	0.5	19			
c. Film plastics	2	227	**6. Other organics**	19	2310
d. Other plastics	1	112	a. Food waste		
			b. Tires and rubber	2	213
3. Glass	8	980	c. Wood wastes	15	1906
a. Refillable bev.			d. Agr. crop residue		
b. CRV glass			e. Manure		
c. Other recycl.	8	980	f. Textiles, leather	2	191
d. Other nonrecyc.			g. Other organics		
			7. Other wastes	8	1053
			a. Inert solids		
			b. HHW and containers		
			c. Other other	8	1053

Table 6.

GENERATOR: RESIDENTIAL WASTE **PATH:** Primary sort

TOTAL POUNDS: 14,899 **DATE:** May-June 1993

PRIMARY SORT DIVERSION

Material	Percent	Pounds	Material	Percent	Pounds
1. Paper	67	10033	**4. Metals**	8	1236
a. Corrugated	7	1015	a. Aluminum cans	2	262
b. Mixed paper	17	2615	b. Bimetal containers		
c. Newspaper	38	5678	c. Ferrous, cans	4	658
d. High-grade ledger	1	178	d. Nonferrous		
e. Other paper	4	547	e. White goods		
			f. Other metals	2	316
2. Plastics	12	1813			
a. HDPE containers	0.5	24	**5. Yard Waste**		
b. PET containers	0.5	34			
c. Film plastics	4	655	**6. Other organics**	2	220
d. Other plastics	7	1100	a. Food waste		
			b. Tires and rubber		
3. Glass	11	1597	c. Wood wastes	1	148
a. Refillable bev.			d. Agr. crop residue		
b. CRV glass			e. Manure		
c. Other recycl.	5	848	f. Textiles, leather	1	72
d. Other nonrecyc.			g. Other organics		
Clear	4	534			
Brown	1	118	**7. Other wastes**		
Green	1	97	a. Inert solids		
			b. HHW and containers		
			c. Other other		

Table 7.

GENERATOR: RESIDENTIAL WASTE **PATH:** Second sort

TOTAL POUNDS: 3,990 **DATE:** May-June 1993

SECOND PRIMARY SORT

Material	Percent	Pounds	Material	Percent	Pounds
1. Paper	48	1902	**4. Metals**	6	270
a. Corrugated	11	436	a. Aluminum cans	1	55
b. Mixed paper	14	545	b. Bimetal containers		
c. Newspaper	19	752	c. Ferrous, cans	2	89
d. High-grade ledger			d. Nonferrous		
e. Other paper	4	169	e. White goods		
			f. Other metals	3	126
2. Plastics	7	267			
a. HDPE containers	0.4	16	**5. Yard Waste**	24	960
b. PET containers	0.3	13			
c. Film plastics	1.5	58	**6. Other organics**	5	185
d. Other plastics	4.5	180	a. Food waste		
			b. Tires and rubber		
3. Glass	10	406	c. Wood wastes		
a. Refillable bev.			d. Agr. crop residue		
b. CRV glass			e. Manure		
c. Other nonrecycl.	7	297	f. Textiles, leather	5	185
d. Other recyc.	3	109	g. Other organics		
Clear	1.4	54			
Brown	1.1	44	**7. Other wastes**		
Green	0.3	11	a. Inert solids		
			b. HHW and containers		
			c. Other other		

Table 8.

GENERATOR: RESIDENTIAL WASTE | **PATH:** Residuals/disposal

TOTAL POUNDS: 48,158 | **DATE:** May-June 1993

RESIDUALS/DISPOSAL

Material	Percent	Pounds	Material	Percent	Pounds
1. Paper	36.0	17337	**4. Metals**	0.3	144
a. Corrugated	1.8	867	a. Aluminum cans		
b. Mixed paper	7.2	3467	b. Bimetal containers		
c. Newspaper	9.3	4479	c. Ferrous, cans		
d. High-grade ledger	0.2	96	d. Nonferrous		
e. Other paper	17.5	8428	e. White goods		
			f. Other metals	0.3	144
2. Plastics	3.5	1781			
a. HDPE containers			**5. Yard Waste**	60.0	28895
b. PET containers					
c. Film plastics	3.3	1685	**6. Other organics**	0.2	96
d. Other plastics	0.2	96	a. Food waste		
			b. Tires and rubber		
3. Glass			c. Wood wastes		
a. Refillable bev.			d. Agr. crop residue		
b. CRV glass			e. Manure		
c. Other recycl.			f. Textiles, leather	0.2	96
d. Other nonrecyc.			g. Other organics		
			7. Other wastes		
			a. Inert solids		
			b. HHW and containers		
			c. Other other		

Table 9.

GENERATOR: RESIDENTIAL WASTE **PATH:** Wastestream

TOTAL POUNDS: 79,987 **DATE:** May-June 1993

WASTESTREAM CHARACTERIZATION

Material	Percent	Pounds	Material	Percent	Pounds
1. Paper	40	32174	**4. Metals**	2.5	862
a. Corrugated	4	3246	a. Aluminum cans	0.5	36
b. Mixed paper	10	8412	b. Bimetal containers		
c. Newspaper	14	11098	c. Ferrous, cans	1	826
d. High-grade ledger	1	274	d. Nonferrous		
e. Other paper	11	9144	e. White goods		
			f. Other metals	1	777
2. Plastics	5	4239			
a. HDPE containers	0.5	60	**5. Yard Waste**	44	35775
b. PET containers	0.5	66			
c. Film plastics	3	2625	**6. Other organics**	3.5	2811
d. Other plastics	1	1488	a. Food waste		
			b. Tires and rubber	0.5	213
3. Glass	4	2874	c. Wood wastes	2.5	2054
a. Other recycl.	2.5	2125	d. Agr. crop residue		
b. Other nonrecyc.			e. Manure		
c. Clear	0.5	534	f. Textiles, leather	0.5	544
d. Brown	0.5	118	g. Other organics		
e. Green	0.5	97			
			7. Other wastes	1	1053
			a. Inert solids		
			b. HHW and containers		
			c. Other other	1	1053

Table 10.

GENERATOR: COMMERCIAL WASTE **PATH:** Tipping floor

TOTAL POUNDS: 14,485 **DATE:** May-June 1993

TIPPING FLOOR DIVERSION

Material	Percent	Pounds	Material	Percent	Pounds
1. Paper	33	4726	**4. Metals**	1	207
a. Corrugated	32	4566	a. Aluminum cans		
b. Mixed paper	1	160	b. Bimetal containers		
c. Newspaper			c. Ferrous, cans		
d. High-grade ledger			d. Nonferrous		
e. Other paper			e. White goods		
			f. Other metals	1	207
2. Plastics	4	591			
a. HDPE containers			**5. Yard Waste**	42	6053
b. PET containers					
c. Film plastics	4	591	**6. Other organics**	15	2208
d. Other plastics			a. Food waste		
			b. Tires and rubber		
3. Glass			c. Wood wastes	9	1338
a. Refillable bev.			d. Agr. crop residue		
b. CRV glass			e. Manure		
c. Other recycl.			f. Textiles, leather	6	870
d. Other nonrecyc.			g. Other organics		
			7. Other wastes	5	700
			a. Inert solids		
			b. HHW and containers		
			c. Other other	5	700

Table 11.

GENERATOR: COMMERCIAL WASTE **PATH:** Primary sort

TOTAL POUNDS: 13,177 **DATE:** May-June 1993

PRIMARY SORT DIVERSION

Material	Percent	Pounds	Material	Percent	Pounds
1. Paper	58	7651	**4. Metals**	8	1016
a. Corrugated	12	1642	a. Aluminum cans	2	307
b. Mixed paper	21	2795	b. Bimetal containers		
c. Newspaper	18	2314	c. Ferrous, cans	5	647
d. High-grade ledger			d. Nonferrous		
e. Other paper	7	900	e. White goods		
			f. Other metals	1	62
2. Plastics	20	2568			
a. HDPE containers			**5. Yard Waste**		
b. PET containers					
c. Film plastics	9	1155	**6. Other organics**		
d. Other plastics	11	1413	a. Food waste		
			b. Tires and rubber		
3. Glass	14	1942	c. Wood wastes		
a. Other recycl.	4	607	d. Agr. crop residue		
b. Other nonrecycl.			e. Manure		
c. Brown	3	398	f. Textiles, leather		
d. Green	1	187	g. Other organics		
e. Clear	6	750			
			7. Other wastes		
			a. Inert solids		
			b. HHW and containers		
			c. Other other		

Table 12.

GENERATOR: COMMERCIAL WASTE **PATH:** Residuals/disposal

TOTAL POUNDS: 37,740 **DATE:** May-June 1993

RESIDUALS/DISPOSAL

Material	Percent	Pounds	Material	Percent	Pounds
1. Paper	41	15473	**4. Metals**	2.5	942
a. Corrugated	18	6793	a. Aluminum cans	0.5	188
b. Mixed paper	1	377	b. Bimetal containers		
c. Newspaper	1	377	c. Ferrous, cans	1	377
d. High-grade ledger	1	377	d. Nonferrous		
e. Other paper	20	7548	e. White goods		
			f. Other metals	1	377
2. Plastics	15	5661			
a. HDPE containers	1	377	**5. Yard Waste**	33	12355
b. PET containers	1	377			
c. Film plastics	10	3774	**6. Other organics**	4.5	1697
d. Other plastics	2	754	a. Food waste	3	1132
e. Polystyrene	1	377	b. Tires and rubber		
			c. Wood wastes		
3. Glass	1	377	d. Agr. crop residue		
a. Refillable bev.			e. Manure		
b. CRV glass			f. Textiles, leather	0.5	188
c. Other recycl.	0.5	188	g. Other organics	1	377
d. Other nonrecyc.	0.5	188			
			7. Other wastes	3	1131
			a. Inert solids	2	754
			b. HHW and containers		
			c. Other other	1	377

Table 13.

GENERATOR: COMMERCIAL WASTE **PATH:** Wastestream

TOTAL POUNDS: 65,402 **DATE:** May-June 1993

WASTESTREAM CHARACTERIZATION

Material	Percent	Pounds	Material	Percent	Pounds
1. Paper	43	27472	**4. Metals**	4	2165
a. Corrugated	20	13001	a. Aluminum cans	1	495
b. Mixed paper	5	3332	b. Bimetal containers		
c. Newspaper	4	2691	c. Ferrous, cans	2	1024
d. High-grade ledger	1	377	d. Nonferrous		
e. Other paper	13	8448	e. White goods		
			f. Other metals	1	646
2. Plastics	13	8441			
a. HDPE containers	1	377	**5. Yard Waste**	28	18408
b. PET containers	1	377			
c. Film plastics	8	5520	**6. Other organics**	5	
d. Other plastics	3	2167	a. Food waste		
			b. Tires and rubber		
			c. Wood wastes	2	1338
3. Glass	4	2130	d. Agr. crop residue		
a. Other recycl.	1	795	e. Manure		
b. Other nonrecyc.			f. Textiles, leather	2	1058
c. Brown	1	398	g. Other organics	1	377
d. Green	1	187			
e. Clear	1	750	**7. Other wastes**	3	1831
			a. Inert solids	1	754
			b. HHW and containers		
			c. Other other	2	1077

Analysis observations and recommendation

Collecting data used to analyze the operations and performance of a waste and recycling facility is difficult. The primary difficulty is adapting records to the operations: keeping distinct loads when materials are being processed for example.

Analyzing information also recognizes methodology limitations and the actual conditions of the study. For example, by knowing that most film plastic pulled from the tipping floor is from opened bags, the high quantities of film represented in tip floor characterizations is understood. To best illustrate the results of the CRRF process characterization, the following observations are presented:

- Tipping floor yardwaste was typically rather uncontaminated. It was generally in bags or pulled in bunches from the floor.
- Mixed paper on the primary line represented several grades that cannot be identified, including some important market grades. Even newspaper was thrown into a general "mixed paper" bin for some loads. Further characterizations from secondary processing may provide accurate figures for these materials.
- The characterization for residential residue is based upon sampling from only one season; during the season heavily influenced by grass clippings. However, the sorting of the sampled materials was fairly thorough and the characterization could be considered accurate for the spring/early summer season.
- The characterization for commercial residue was based upon two samplings during the summer months and may be considered fairly accurate for the season.
- Yardwaste represents the greatest variations both seasonally and by generator type, including commercial.

Recommendations

- Additional seasonal characterization of residue should be performed, particularly for residential waste. Commercial characterization is also influenced by seasonality, although typically less so.
- Characterizations might be considered for commercial high-graded loads to analyze effectiveness.
- Continued characterization of "blue bag" materials will eventually provide figures which can be used to more accurately characterize total quantities.
- Extensive characterization should be conducted on secondary sort operations. Plastics and paper in particular have not been accurately analyzed. To perform secondary characterization, loads must be kept distinct, that is, gross categories of materials pulled from the primary line must be quantified, kept separate and then sorted for characterization on the secondary line.
- Standardized, computerized forms should be developed and used to record daily quantities. This will assist in developing reports for reporting periods, such as seasonal reports.

ISSUES IN CRRF OPERATION

Background

Several key issues associated with CRRF implementation were identified, including broad, long-term elements important to the success of the concept. These issues include the characteristics and marketability of the humus product, integration of municipal source separation, issues in regulatory compliance, and the design and operation of the CRRF anaerobic digestion system. As the Folsom CRRF becomes fully operational, further demonstration will determine the viability of the several unique programs and technologies evaluated.

Issues identified

In addressing the issues, much of the basis for the discussion was produced during the implementation stage of the City of Folsom CRRF in conjunction with demonstration projects and market studies conducted under the interagency agreement between PIA and the IWM Board. Following are the four issue identified:

- Vessel Design
- Humus Characteristics
- Source Separation of Materials and its Impact on CRRF Composting
- Regulatory Issues

Each of these issues received the attention of the many researchers, technicians and other experts associated with the implementation of the Folsom CRRF project. The issues are addressed in the order above. Following these discussions is the guide to anaerobic composting operation.

VESSEL DESIGN

Background

Design of the CRRF anaerobic digestion vessel was an involved, carefully considered engineering accomplishment. Proper design is vital for a successful process. In the design of a digester vessel to conduct anaerobic composting, the PIA evaluated several factors:

1. Size of the wastestream
2. Characteristics of the wastestream
3. Ease of operation
4. Material feeding
5. Construction materials

PIA based much of its evaluation on the anaerobic process research conducted by the University of California, Davis civil and environmental engineering department under the direction of Drs. George Tchobanoglous and Masoud Kayhanian. Their pilot study addressed separated municipal organic wastes such as that found in the City of Folsom.

In 1992, PIA constructed a small test vessel to evaluate various construction techniques and equipment. The vessel was built adjacent to the City of Folsom Return to Custody facility. Various mixtures of organics were tested during a several-month period. PIA contracted Dr. Doug Williams of the mechanical and agricultural engineering department at California Polytechnic State University, San Luis Obispo, to provide preliminary design for the full-scale composting vessels.

PIA's approach involved integrating vessel design into the overall operations of material handling, monitoring and operations. Factors such as personnel operation, premixing, ease of assembly and maintenance are unique to the CRRF concept. Many of these unique features are due to the use of convict labor to build and operate the digestion system. Simplicity, security and dependability are important features in the design.

The following report describes how the vessel design addressed these factors. Final design was conducted by the engineering consulting firm of CH2M Hill; drawings are included in the report. Construction will begin and be completed in 1994. CH2M Hill will provide construction supervision. Actual construction will be performed by PIA personnel supervising inmate labor.

Process overview

A high-solids anaerobic digestion/aerobic drying process for the organic fraction of municipal solid waste (MSW) has been demonstrated on a pilot scale by the University of California, Davis. The system provides biogas recovery followed by aerobic (with air) drying for the production of humus material.

The digestion process operated at UCD research engineers was based on a concentrated slurry of organic waste material retained in an enclosed vessel for 30 days at a temperature between 130 and 140 degrees F. The principal feature of the UCD process is to maintain a slurry at about 25 percent solids or more-- much greater than the 5-10 percent range for digesters used for wastewater treatment plants or agricultural waste. The higher solids concentration allows more material to be treated in a given volume, reducing cost of construction and operation.

However, mixing of high-solids slurry is not easily achieved. To overcome this problem, it is proposed to use a semi-dry (18-20 percent total solids) anaerobic digestion process. The semi-dry anaerobic process will maintain the slurry in a liquid-like state to allow mixing and removal of the treated waste from the digester using conventional equipment. The challenge is to achieve a balance between high-solids and mixing so that the digestion process is economical to construct, relatively easy to operate and maintain by inmate labor.

Digestion facilities

The proposed facilities will anaerobically digest 78 tons per day (tpd) of organic waste material. This represents the highest amount of organic material that can be recovered from the 100 tpd of MSW. The project could be constructed in two or three phases.

The first phase consists of one 26-tpd digester. This digester will confirm the suitability of feeding and mixing equipment. Modifications will made to the second and third digesters based on operating experience of the first digester.

The digestion facilities include a receiving station, one concrete digester, a gas collection system, a stream generation facility and a compost area. The CRRF material recovery facility will provide the organic material for the digester. The material will be shredded and ground prior to delivery by truck and trailer.

Water will be added in the trailer or added as the waste material is fed into the digester. The water will be pumped from the CRRF water discharge system. Steam will be injected directly into the dilution water or into the digester for heating. Off-gas from the digester will be collected as a fuel for the steam boilers or burned in a waste gas burner.

Each day, digested material will be removed to the compost curing area, mixed with yard waste or other bulking amendments, and aerobically cured to produce a suitable soil amendment and other useful compost products.

The following table presents a design summary of the PIA CRRF anaerobic digestion system. Following the table, the facilities designed will be presented.

Table 14.

DIGESTION SYSTEM DESIGN SUMMARY

Municipal solid waste	
Total	100 tons/day
Organic fraction	78 tons/day
Phase 1 organic fraction	26 tons/day
Organic waste mixture	
yard waste	40 percent
Mixed paper	36 percent
Food waste	24 percent
Receiving station	
Metering bin volume	200 cubic feet
Number of screw conveyors	1
Anaerobic digester	
Length	120 feet
Width	32 feet
Height	22 feet
Liquid volume	517,000 gallons
Material	Reinforced concrete
Digester mixers (type 1)	
Number	2
Type	Dual 3-blade impeller
Horsepower, each	20 hp
Speed	20 rpm
Digester mixers (type 2)	
Number	2
Type	3-blade impeller
Horsepower, each	15 hp
Speed	30 rpm
Digester heating	
Type	Steam
Boiler rating	60 hp
Heat output	2,000,000 BTU/hour
Digester operating conditions	
Detention time	30 days
Temperature	130-140 degrees F.
Solids content	18-20%
Digester pumping	
Type	Progressive cavity
Capacity	120 gallons/minute
Horsepower	30 hp
Speed	100 rpm

Anaerobic digester

The anaerobic digester is an enclosed concrete vessel 22 feet high by 32 feet wide and 120 feet long. The digester features roof-mounted mixers, gas collection system, inspection manholes, sampling wells and entrance openings with sealed cover.

The digester is a reinforced concrete structure designed for earthquake loads. The digester walls could be constructed using concrete masonry block walls as forms or by renting form work. A coal tar epoxy with a polyamide, anti-corrosive primer is proposed for the digester roof and metal openings on the roof. Cathodic protection is not proposed, but could be added in the future as required.

Mixing is provided by two, single-three-blade and two dual-three-blade impeller mixers. The mixers are designed for concentrated slurries. However, the blades may be fouled by accumulation of rags or other stringy materials. The proposed method of positive sorting of municipal solid waste to eliminate this type of material is important to the successful operation of the mixers.

Gas collection consists of two 36-inch-diameter openings on the roof. The gas openings (bonnets) extend above the digester roof to separate the gas piping from the digester liquid or foam from an upset digester. The gas flows from the bonnet to a separator to remove foam and liquid entrained in the gas as it leaves the digester.

Digester gas consists of a 50/50 mixture of carbon dioxide and methane based on pilot studies at U.C. Davis. The characteristics of the organic feedstock may affect the gas mixture. The digester gas collection system must be maintained under positive pressure to avoid the introduction of air and the possibility of explosion. Volume changes within the digester must be controlled to prevent a vacuum which draws air into the digester.

Digester gas piping is designed to limit the gas velocity to maintain low line pressure losses and prevent the carryover of moisture from the digester. Additional features to be provided include sediment and condensate traps, gas metering, pressure gauges, isolation valves, flame arresters, check valves and pressure/vacuum relief valves. Collected gas will be used to heat the digester or burned in a waste gas burner. Digester heating and gas burning are described in the following section.

Sampling wells are used to collect digester samples during operation. The well is a six-inch pipe extending into the digester. Samples can be taken without releasing digester gas because the well opening extends into the digester liquid. Entrance into the digester is made through an eight-foot by 10-foot opening with a solid concrete cover, or two-48-inch manholes. One manhole is located on the roof and one manhole is located on the end wall.

The digested material is moved to the compost areas using a progressive cavity pump, a metal screw turning in a rubber or other resilient material cylinder. The cavities formed between the screw (rotor) and the cylinder (stator) trap the materials and carry it to discharge. The screw turns at speeds of 100 rpm or less to reduce wear. The discharge piping will include provisions to recycle digester contents to the front end of the digester.

Ideally, equipment selection should be made from tests on waste material produced from the Folsom CRRF. The organic fraction could be digested with the existing pilot digester at UC, Davis. The digested material properties could then be determined to better select mixing and pumping equipment.

Because no full-scale digester operates in the proposed range of solids concentrations, startup of the Folsom digester will occur at lower solids concentrations. By incrementally increasing the solids concentration, PIA staff will be able to observe a gradual change in equipment performance. Operating experience will determine appropriate digester feed rates and solids concentrations.

Steam generation building

In the digestion process, organic material is converted to biogas, water, and digested organic material by micro-organisms. The rate of conversion is hastened at high temperatures. The ideal temperature range is 130-140 degrees F. Heat is normally generated by the microorganisms' activity, supplemented by the addition of steam.

Steam is produced in a steam boiler burning natural gas or digester gas. The proposed boiler is capable of using both fuels. The boiler is housed in a 25-foot by 40-foot building. Space is available to add one or two more boilers for the future digesters. The building has an electrical control panel for the digester equipment, water treatment units for the boiler feed water, recording equipment and miscellaneous controls.

Biogas is produced at fluctuating rates; it is moist and corrosive to metal under long term operations. Hydrogen sulfide in digester gas is corrosive. Boiler temperature must be selected to remove hydrogen sulfide from the biogas, the biogas must be scrubbed.

Digester gas not used in the boiler must be burned in a waste gas burner. The burner includes an all-weather pilot with an ignition system. Propane or natural gas will be used as a pilot fuel. Air quality regulations require a high-temperature burner operating at 1,400 degrees F with a minimum residence time of 0.6 seconds.

Instrumentation and control

Feeding the digester and pumping to remove digested material will be controlled by manual on/off switches. Mixing equipment will be operated from time clocks with manual override switches. The boiler operation will be modulated by continuous digester temperature measurements. Digester level will be measured with an ultrasonic level indicator or diaphragm pressure sensors. The digestion process will be monitored for digestion problems. Possible indicators are:

- Alkalinity
- Volatile fatty acid concentration
- Gas production
- Percent methane in gas
- pH
- Ammonia concentration

Gas production rate and methane concentration are proposed for continuous measurement. However, continuous methane concentration measurement is unreliable with available instrumentation. Generally, carbon dioxide percentages are monitored to estimate methane concentrations. The instrument for measuring digester gas flow rate is the thermal mass flow meter. All other digester indicators will be measured in the laboratory from grab samples taken from the digester. Sample frequency can vary from daily to weekly based on operating experience.

Digester solids concentration must be carefully controlled to maintain the desired operating conditions. Total solids content should be measured daily at two locations within the digester and at the digester discharge from the digester. Solids content will be controlled by water addition during digester feeding.

Electrical distribution system

The electrical distribution system consists of the interconnection between the electrical power and the supply to loads for the anaerobic digestion system and the wastewater transfer station. The electrical distribution system contains the following components:

- New circuit breakers for the existing motor control center located in the CRRF building.
- New motor control center at steam generation building.
- Lighting and power panels.
- Distribution transformer.
- Non-fused disconnect switches.

The electrical service to the existing motor control center in the CRRF building is provided via an existing transformer located outside and to the north of the CRRF building. Modifications to this control center are required for the installation of a new 600A circuit breaker for the anaerobic digestion system.

To accommodate the new circuit breaker, two existing spare cubicles will be removed to make room for the new circuit breaker. The new circuit breaker will be used as the main protective device for the feeder to the new motor control center located in the steam generation building.

Power to the transfer pumps at the wastewater transfer station will be provided by two new combination starters in the existing control center.

A new control center will be installed in the steam generation building. It will be rated for 600A, 480/277 volts and will provide power to all electrical equipment associated with the anaerobic digestion system. Except for the lighting and power panel feeder breakers, all circuit breakers will be equipped with electric motor starters.

One lighting panel will provide branch circuits for interior and exterior lighting of the facility. A power panel will provide branch circuits to small motors, controls, alarms and miscellaneous receptacles. A dry-type distribution transformer will step down the voltage from 480V, three-phase, to 208/120V, three-phase, for the power panel.

Non-fused disconnect switches will be provided for the mixers, conveyors and transfer pump associated with the anaerobic digestion system. Each of these disconnect switches is connected to the new motor control center. Non-fused disconnect switches will also be provided for the transfer pumps located at the wastewater transfer station. These disconnect switches are required by the National Electrical Code (NEC) since the motor controllers are not within sight of the electrical motors.

Electrical site work

Four existing four-inch conduits are located outside the CRRF security fence. A new pre-cast concrete pull box will be installed at this location to intercept the conduits. Pull boxes will be installed for conduit runs from the stream generation building and from the wastewater transfer station to the existing motor control center in the CRRF building.

Of the four existing four-inch conduits terminating in the new pull box, two will be used to interconnect the existing and new control centers. The other two conduits will each be used to interconnect the wastewater station transfer pumps to the existing control center.

Additional new conduits will be routed between the new motor control center and the anaerobic digestion equipment. In addition to the power conduits, two conduits will be installed for the communication system. These conduits will be routed between the telephone backboard in the steam generation building and the existing telephone panel in the CRRF building.

Ceiling-mounted, florescent fixtures will be installed inside the steam generation building. Exterior, high-pressure sodium flood lights will be installed outside the steam generation building and anaerobic digestion system.

Control, alarm and communication systems

The control system consists of manual and automatic motor controls used for the anaerobic digestion system. The alarm system consists of local fire alarms for the steam generation building. The fire alarm system will be a self contained unit with audible and visible alarm.

The communication system includes the installation of a new telephone backboard in the steam generation building. A telephone jack will be installed in the boiler area and connected to the existing telephone backboard in the electrical room of the MRF building.

HUMUS CHARACTERISTICS AND END-USE IMPLICATIONS

Introduction

The anaerobic composting process to be conducted at the City of Folsom CRRF is unlike any other composting operation currently being conducted in California, or the country. The anaerobic composting processs uses a variety of organic materials derived from a municipal wastestream. A key byproduct of the process is methane gas suitable for commercial combustion and power generation. The other key byproduct is the humus material.

A significant issue in the viability the anaerobic digestion technology is the ability to market the humus material as a soil amendment or for other end uses, such as biomass power production fuel. A key to understanding this issue is the characteristics of humus from the CRRF anaerobic composting process.

CRRF humus characteristics presents a unique issue because of the unique anaerobic process used to compost a unique feedstock stream composed of a range of biodegradable organic materials separated from the municipal wastestream by the CRRF material recovery process.

Humus characteristics of Folsom CRRF facility are not yet available. However, a pilot study conducted at UC Davis performed various analysis on humus and the results of their study is reported here. Similar results could be obtained from the CRRF system, since its feedstock is as clean the UC Davis source separated feedstock. The characteristics evaluated include:

- Physical characteristics.
- Chemical characteristics.
- Nutrient characteristics.
- Phytotoxic characteristics.

Physical characteristics

The physical characteristics of the humus material are moisture content, bulk density, particle-size distribution (using screen test), color and odor. The physical characteristics of humus are summarized in the following table:

Table 15.

CRRF HUMUS CHARACTERISTICS

ITEM	UNIT	VALUE OR DESCRIPTION
Moisture content	%	65
Bulk density	(kg/m3)	35
Color		dark brown
Odor		none

Odor is usually associated with the degradation of the organic fraction of the waste to be used as feedstock in this process. Using the anaerobic composting process, it was possible to remove up to 90 percent or more of the biodegradable organic fraction of the feedstocks, under optimal conditions. The removal of highly biodegradable organic substrate minimizes the release of odors and reduces the odor potential of the residual material.

The humus material obtained from UCD anaerobic composting is quite fine, with about 90 percent of the total product by weight in the range of one millimeter or less. The following table illustrates the particle size distribution by screening sieve.

Table 16.

HUMUS PARTICLE SIZE DISTRIBUTIONS

SIEVE NUMBER	SIEVE SIZE (MM)	PERCENT OF TOTAL WEIGHT
8	2.362	11.9
20	0.833	28.9
40	0.351	25.4
80	0.175	21.3
100	0.147	7.8
200	0.074	4.3
Pan	-	0.4

Chemical characteristics

The chemical characteristics of the humus were determined by ultimate analysis, elemental analysis and fiber analysis. Energy content as high heating value was determined by a bomb colirimeter. Energy content was calculated as 14/8 MJ/kg. The results of the elemental analysis is reported in the following table:

Table 17.

ELEMENTAL ANALYSIS

CHEMICAL	UNIT	VALUE
Ca	%	1.08
Mg	%	0.34
Mn	ppm	175
Fe	ppm	710
Cu	ppm	578
B	ppm	64
Zn	ppm	376
Mo	ppm	20
Al	ppm	94
Na	%	0.3
Co	ppm	not detected
Cd	ppm	1.55
Cr	ppm	34.3
Ni	ppm	186
Pb	ppm	213
Si	ppm	21
Ba	ppm	136
As	ppm	1.04
Ag	ppm	1.13
Se	ppm	<1
W	ppm	73

Table 18.

ULTIMATE ANALYSIS		
CHEMICAL	UNIT	VALUE
Carbon	%	32.4
Hydrogen	%	3.8
Nitrogen	%	1.9
Oxygen	%	31.4
Sulfur	%	0.25
Chlorine	%	0.30
Residue	%	30

Biological characteristics

The biological characteristics of concern in the humus are the biodegradable volatile solids and pathogenic organisms. The biodegradability and pathogenic characteristics of the final humus were determined by lignin content test and total coliform test respectively.

The results of these two analyses are presented in the table below. As can be seen, no pathogens were detected in the humus produced by the anaerobic composting process. Because both the anaerobic digester and aerobic biodrier in this process are operated in the thermophilic rate (54-58 degrees Celsius), it has been determined that almost all pathogens present in the MSW are eliminated.

Table 19.

BIOLOGICAL CHARACTERISTICS		
CHARACTERISTIC	UNIT	VALUE
Biodegradable fraction	% of volatile solids	8.8
Total coliform	MPN/100ml	none
Fecal coliform	MPN/100ml	none
Streptococcus/enterococcus	MON/100ml	none

Nutrient characteristics

Other important humus characteristics are the presence of nutrients, pH, electrical conductivity (EC), cation exchange capacity (CEC), humification, phytotoxicity and total salinity. The characteristics play an important role when the humus is used as a fertilizer or soil amendment. These characteristics are presented in the following table.

Table 20.

NUTRIENT CHARACTERISTICS		
NUTRIENT/ITEM	UNIT	VALUE
N	%	1.9
NH4-N	ppm	44
NO3-N	ppm	8
C/N	-	17
P	%	0.23
PO4-P	ppm	170
K	%	0.73
SO4-S	ppm	747
pH	-	8.2
EC	mili mhos/cm	9.4
CEC	meq/100g	30

Phytotoxicity

As organic matter is digested, whether aerobically or anaerobically, intermediate compounds are first produced and then further digested into simpler, more stable compounds. Some of these intermediate compounds, such as acetic acid, are "phytotoxic," that is, inhibiting both germination and plant growth. The absence of these compounds is an indication that a compost if fully humified.

Direct testing for these intermediate compounds is difficult. The composting industry is, therefore, in the process of developing simple tests to evaluate the level of humification of a compost. The simplest and most directly applicable test in the In Vitro Germination Test, using cress seeds. Since cress seeds were unavailable, lettuce seeds were used and the germination time extended from 24 to 48 hours.

In performing the In Vitro Germination Test, seeds were incubated in petri plates on filter paper. The filter paper was demapened with varying concentrations of compost solution. This solution was produced by mixing compost with water and then vacuum filtering. A compost is considered to be phytotoxic due to incomplete humification if a 30 percent solution has a germination rate of less than 60 percent.

Test results

A 30 percent solution of the compost produced by the high-solids anaerobic digestion process has a germination rate of 4 percent, much lower than 60 percent germination which indicates phytotoxicity.

The compost produced by the high-solids anaerobic digestion process is, therefore, not completely matured and the aerobic curing of the anaerobic digestate must be extended if the compost is to be used as potting soil. The air drying units used in the pilot plant may not promote sufficient aerobic composting.

These results indicate the importance of the aerobic curing and drying. PIA will not be using the air drying units used in the pilot study phytotoxicity tests. Care must be taken to ensure complete composting if a fully humified compost is desired, since the anaerobic digestion process does not produce a fully humified digestate.

Because the compost produced by the pilot plant is not fully matured, a compost solution diluted to 20 percent has a germination rate well above 60 percent. The compost can, therefore, be used as a soil amendment if the proportion of compost to soil does not exceed 20 percent. If the humification of the compost is increased due to increased aerobic composting, the allowable mix percentage will increase.

Recommendations

The phytotoxic characteristics identified in the anaerobic digestate may can be addressed by various operational adjustments and other means such as blending with other materials. Following are recommendations made by the UC Davis Department of Civil and Environmental Engineering:

- If the compost is to be used as a potting soil, soil amendment or sod growing medium, germination testing should be done periodically to verify the proper use of the humus. Germination testing is simple and inexpensive and can be performed by operators.
- Aerobic curing of the anaerobic digestate should be carefully monitored to ensure complete humification.
- If humus does not pass germination tests, buyers should be told the allowable mix percentage.
- If humus is to be used as a sod growth medium, germination testing should be done with the grass seeds to be used since they may be more sensitive to phytotoxic compounds than the cress or lettuce seeds usually used in the tests.

SOURCE SEPARATION IMPACTS ON CRRF OPERATIONS

Background

The City of Folsom conducted several demonstration projects to assess the viability and impact of source-separating organic materials for use in the anaerobic composting operation at the City of Folsom CRRF. The source-separation efforts were assessed for their improvements to CRRF operations, capacity and material market value.

The demonstrations included projects designed to collect separated yardwaste from homes, to collect "wet" compostable materials from businesses such as restaurants, and to collect separated "wet" household waste in its program of co-collected household recyclables.

Several issues associated with these programs impact on CRRF anaerobic composting:

1. Quality of the collected materials.
2. The estimated quantities of the materials collected.
3. Handling and preprocessing of the collected materials.
4. Impacts on the efficiency of CRRF separation and composting processes.
5. Cost effectiveness of the separation programs.

In analyzing these factors, data was collected by the City of Folsom for each of the demonstration projects. Data included characterization of the materials and monitoring of the viability of the demonstration projects by criteria such as participation.

In order to report on the issue, the City of Folsom acquired extensive data and information on the demonstration projects and the facility. It analyzed potential impacts in the areas of handling, preprocessing and composting feedstock quality. The quantity and characteristics of material handled by the CRRF during the demonstration phase was carefully documented.

This report includes recommendations for adjustments in operation either of the City source separation programs or CRRF process. First the implementation of the key programs are summarized. Following the implementation summary, the results are presented for each individual demonstration: residential, commercial and yardwaste.

Summary

The CRRF program is designed as the cornerstone of a successful integrated waste management program for the City of Folsom. Source separation can provide significant benefits to a comprehensive, integrated waste management system. Source separation can improve recyclable material quality and reduce the waste management burden at the source of waste generation.

Source separation is also expected to provide additional, unique benefits to the CRRF program, particularly the composting element of the program. Diversion of materials from the primary sorting operation, the picking of materials from mixed residential or commercial waste, improves and increases facility throughput. Materials can be directly staged to the secondary picking lines, where recyclables can be processed for markets. Yardwaste waste in particular is a target for source separation in conjunction with CRRF operations, for two major reasons:

- Yardwaste such as grass clippings are more difficult to separate on the primary picking line. Yet yardwaste represents one of the largest wastestream components, particularly during the spring and fall seasons.
- Yardwaste is an important feedstock in the CRRF composting operation. It is also an accessible feedstock; considerable yardwaste is already source-separated (in plastic bags) or can feasibly be separated.

The City of Folsom is typical of much California municipal waste collection, using automated 20-yard, side-loading vehicles for residential collection, front loading vehicles collecting primarily four-yard drop bins for commercial collection.

In order to fully realize the potential of the CRRF program, the City, in its Source Reduction and Recycling Element (SRRE), selected several unique source separation programs. These were demonstrated by the City of Folsom solid waste division. The demonstrations sought to divert the maximum amount and types of materials in a manner integrated with facility and City operations. Special focus was placed on separated yardwaste as feedstock for the CRRF anaerobic composting process.

The demonstrations tested the programs in a typical municipal environment, and their integration with CRRF operations. Final recommendations for full-scale implementation were based on the demonstration results.

Residential source separation: "blue bag" program

The residential recycling program was based on the "blue bag" program of using plastic bags to collect recyclables. The program has significant benefits: the bags can be "co-collected," put directly in waste containers for collection. This eliminates the requirement for extra collection vehicles on the streets. No additional labor is required, a benefit particularly where automated collection exists, such as Folsom.

Success of Folsom's "blue bag" residential source separation was limited. Problems included bag breakage and low participation. However, benefits to further consider included the possibility that newspaper separation, in particular, could be improved in conjunction with the CRRF operations. The high degree of labor afforded by the CRRF was believed to provide an opportunity to collect a much broader range of recyclables through a bag program, including yardwaste.

Commercial source separation: "wet/dry" programs

The City, in its SRRE, selected "wet\dry" source-separation programs for commercial accounts specially suited to the advantages of the CRRF. "Wet/dry" commercial collection is in use in a variety of forms elsewhere. Generally, "wet/dry" programs encourage commercial locations to designate a collection container for paper and other "dry" recyclables such as cardboard. A remaining "wet" putresible waste is landfilled.

The high degree of CRRF manual separation allows the City to maximize the potential of "wet/dry" commercial collection. "Dry" containers can be provided for everything from cardboard to textiles; mixed office paper can be included with cardboard. These materials can be separated into appropriate market grades on the CRRF secondary sorting line.

In addition, special "wet" containers could be provided to commercial accounts such as restaurants for collection of source-separated organics, such as food waste. Such "wet" source-separated materials may provide a quality feedstock for the CRRF composting operations.

Food waste comprises a far higher proportion of commercial waste than it does in residential waste. According to the City's SRRE, 14 percent of commercial waste is food waste, while only 7 percent of residential waste is food waste. Commercial accounts with particularly high food waste can be readily identified and targeted.

The City designed and evaluated several approaches to segregating "wet" and "dry" commercial waste. Demonstration was implemented on a limited scale. This demonstration is discussed in the implementation section below.

Yardwaste source separation

Additional programs to source separate yardwaste were designed by the City but have not been tested. These programs are intended to further assure the benefits of diverting yardwaste from the municipal wastestream. Targeted generators would include landscaping contractors and other generators who might haul organic waste themselves directly to the County landfill. The programs, as they were selected in the City's SRRE, include:

<u>Yard Waste Collection Program.</u> Under this program, the City would provide a local yardwaste collection program for residents and businesses who would otherwise self-haul yardwaste to the county landfill. This will allow the City to capture this material for composting, while at the same time providing additional service to City residents.

<u>Mobile Dropoff Program.</u> Under this program the City puts out special dropoff bins for collection of yardwaste generated by residents. This program emphasizes neighborhood collection events in the spring and is tailored to be conducted in conjunction with special cleanups.

<u>Mandatory Collection of Wood and Yard Waste.</u> Under this program, the City would evaluate prohibiting residents from including yardwaste for waste collection. This would require residents to use one of the adopted City-operated opportunities for yardwaste and woodwaste collection. Or residents could otherwise reduce their generation at the source.

The City demonstrated yardwaste source separation in conjunction with its residential source separation programs only. Further attention will be given at a later date to the alternatives and generators presented here.

Implementation

Program design was performed by the consulting firm California Resources. The City of Folsom Solid Waste Division conducted implementation of the demonstrations, with direct oversight by the City recycling coordinators Michael Rock and Kevin Miller. Project management for the City was conducted by division chief Robert Bailey. Analysis of the demonstration was performed by California Resources.

The demonstrations were designed in the winter of 1992 and spring of 1993. Implementation of the residential source separation (blue bag) program began with door-to-door education of the 325-home demonstration area in April, 1993. Implementation of dry, cardboard commercial source separation began in May, 1993.

Residential source separation

Actual participation by the 325-home demonstration area was preceded by a month-long education effort. The intensity of the education effort was intended to achieve the resident awareness which would take longer to develop for a full scale program.

City recycling staff knocked on virtually every door in the demonstration area and in most cases spoke with someone at the home. Participating households were presented with a box of "blue bags" manufactured by Glad. Each box contained ten bags. This was believed to be sufficient for a five-week period, at two bags each week during that period.

Different thicknesses of bags were tested by distributing one thickness to half the demonstration households, another thickness to the other half. Half received bags 1.01 millimeters in thickness, the other half received bags 1.75-millimeters thick. All the bags were otherwise identical, 13 gallons in capacity. All households were also given one larger, 33-gallon clear bags for yardwaste.

Residents were instructed which materials to put in the bags. The promotion material also directed the residents to supermarkets where blue bags could be purchased after the free "samples' had been used up. Several stores in Folsom had agreed to carry the bags for sale and stock of the bags were already on the shelves.

The City's residential co-collection of recyclables featured a three-bag approach: one for organics, including food waste; another for mixed paper; the last for mixed recyclables containers, such as cans and bottles. The test began in April of 1993 and finished (for the purposes of analysis) at the end of July, 1993.

Commercial source separation

Initially, City staff and consultant considered separate collection of wet and dry recyclables in separate containers, such as 90-gallon toters or four-yard drop bins. This, however, would require a separate collection vehicle collecting either wet or dry separated routes. This was not possible due to demands on collection vehicles.

The City compiled a list of candidate commercial sites to implement wet and dry bagged separation of recyclables. Initial data on the quantities of wet and dry materials were acquired from site "surveys" or audits of current generation, with a separation program recommended based on the findings.

In the end, however, the City opted to implement separated commercial recyclables from a different approach. Drop-bin containers were modified for cardboard collection and a route started on a once-a-week basis. Initial quantities of cardboard generated were about half a ton of adequate quality material.

City staff has moved to double the bins distributed for separated cardboard collection. In the meantime, two expansions of the commercial source separation effort are being considered. The first would expand upon the cardboard collection efforts. This would entail including other mixed paper in the cardboard bins, thus generating large quantities of dry paper. The other approach includes site-by-site implementation of wet and dry collection. Major generators in the community are being considered for targeting, such as the local school district.

The two approaches-- separate containers versus bagged, co-collected recyclables-- may, in the end, be complementary in achieving source separation at the greatest number of commercial locations. Smaller generators may be more likely candidates for co-collected bagged materials, wet or dry. Larger locations, generating specific dry materials such as paper, or wet materials, such as cafeteria waste in large quantities, may be better candidates for separate containers.

Yardwaste source separation

A program for drop-bin collection of residential yardwaste was designed. This program would allow City residents to rent City four-yard drop bins at special rates to dispose of yardwaste only. Constraints on City vehicles and personnel hours during the implementation of the CRRF prevented demonstration of this program.

The City also investigated providing a central site for yardwaste dropoff to be provided to City-contracted landscapers. According to a City survey, several tons a week of clean yardwaste is generated by these contractors alone and is self-hauled by the contractors for landfill.

Demonstration of this alternative encountered obstacles. A permanent dropoff site could not be found. Also 40-yard rolloff boxes are required to implement yardwaste dropoff. These were not available to the City during the demonstration period.

These programs were designed specifically to meet special needs entailed in CRRF operations. Public CRRF access is restricted; no public CRRF dropoff can be provided. Significant amounts of yardwaste are transported directly to landfill by residents and businesses, an hour roundtrip from Folsom. Providing a closer opportunity to dropoff these materials provides a service to residents while capturing compostable feedstock for the CRRF.

Residential source separation results

The "blue bag" residential program could be a major benefit to CRRF operations, according to the demonstration project results. A far greater range of recyclables can be separated without significant additional cost to the City. The separated materials, particularly yardwaste, could benefit the overall CRRF program. Source separation may provide with cleaner materials; improved operations and throughput at the material recovery facility; and higher revenues from recyclable sales.

However, to achieve these source separation benefits the demonstration program must overcome several obstacles: low participation and contamination. The contamination is not a significant problem because of the labor afforded by the City's CRRF. However, low participation and contamination both indicate the need for aggressive education to motivate and instruct residents to participate in improving their City's recycling and waste diversion efforts.

Participation

In conducting the residential, "blue bag," cocollection of recyclables, data was collected which might indicate residents response to the program. Other statistics were collected by a City assistant riding in collection trucks on the demonstration route. The assistant recorded households which put bags in collection containers. The assistant was able to observe the bags as they were tipped into the hopper of the automated collection vehicle. Following is a tabulation of the results.

Table 21.

PARTICIPATION IN CITY OF FOLSOM
RESIDENTIAL "BLUE BAG" COCOLLECTION OF RECYCLABLES
325-HOME DEMONSTRATION AREA

DATE	NUMBER PARTIC.	PERCENT PARTIC.	DRY, PAPER BAGS	ORGANIC BAGS	RECYCLABLE BAGS
6/7/93	67	(1) 33%	58	28	29
6/14/93	59	18%	40	39	21
7/19/93	25	(2) 17%	40	24	23
8/2/83	55	17%	18	0	26

(1) City staff estimate that only 200 homes in the demonstration area had been contacted to participate at this date.

(2) City staff were only able to record about half the demonstration area, or about 150 homes.

As the table shows, about 17 percent participation might be expected on a weekly basis, allowing for much higher initial participation which is traditionally due to both initial enthusiasm and "stockpiled" recyclables in the household. It should be noted, however, that tipping floor observation and informal observation on the route indicated a significant drop in participation in subsequent weeks.

Another indicator of participation is by quantity; how much material each household separates for collection. An estimate of participation by quantity for the Folsom demonstration can be obtained by assigning weights per bag collected. To arrive at figures for individual bags, the bags from a sample day were all weighed and the average weight per bag recorded. Following are the results:

Table 22.

AVERAGE BAG WEIGHT RESIDENTIAL "BLUE BAG" COCOLLECTION OF RECYCLABLES			
BAG TYPE	**TOTAL BAGS**	**TOTAL POUNDS**	**AVER. WEIGHT/BAG**
Dry paper	15	314	21
Recyclable containers	13	220	17
Yardwaste/organics	10	246	25

Using the average bag weights, numbers of bags tallied and household participation figures, a estimate of the quantity per participating household can be estimated. The table below uses the bag figures from the July 19, 1993 tally of bags. The figures for this date appear to be the most typical. For purposes of comparison, household quantity of participation for the City and County of Sacramento are cited. "Set-outs" refer to materials set out by an individual household or account.

Table 23.

POUNDS PER SETOUT RESIDENTIAL "BLUE BAG" COCOLLECTION OF RECYCLABLES 59 PARTICIPATING HOUSEHOLDS				
TYPE OF RECYCLABLE BAG	**TOTAL NUMBER**	**AVE. BAG WEIGHT**	**TOTAL WEIGHT**	**AVE. PER HOUSEHOLD**
Dry, paper	40	21	840	14.2
Recyclable containers	21	17	357	6.0
Yardwaste/organics	39	25	975	16.5
TOTAL	100	63	2172	36.7

Characterization

The higher set-out poundage might be expected: the yardwaste collected by the blue bag system increases the weight of set out significantly. However, this is not the only difference. The "dry" bag of recyclables is the most frequently put out by households. This may be due to the weekly need to recycle newspapers; three-bin systems typically feature 70 percent or higher weights of newspaper in weekly totals.

However, characterization of the bagged materials reveals that the dry, paper bag contains much more than just newspaper. Other paper such as white ledger contributes significantly to the paper bag's total. This might indicate that other recyclables in addition to yardwaste are increasing the per household quantity set out with the blue bag system.

The following table characterizes the dry paper bag and the recyclable containers bag. Yardwaste can be characterized as composed of grass clippings, tree trimmings and the other organic material typical of yardwaste. No kitchen scraps were found in the organics bags. City and County of Sacramento figures were acquired from recycling officials.

Table 24.

CHARACTERIZATION OF "BLUE BAG" RECYCLABLES DRY PAPER BAG		
MATERIAL	**PERCENT BY WEIGHT**	**PERCENT BY VOLUME**
Old newspapers (ONP)	58	54
Corrugated (including brown bags)	8	10
Highgrade ledger (office paper, etc.)	26	25
Other paper (tissue, mags, towels, boxboard)	7	10
Nonpaper (steel cans, plastic pens, etc.)	1	1
TOTAL	100	100

Table 25.

CHARACTERIZATION OF "BLUE BAG" RECYCLABLES RECYCLABLE CONTAINERS BAG		
MATERIAL	**PERCENT BY WEIGHT**	**PERCENT BY VOLUME**
HDPE (high-density polyethylene)	3	9
PET (polyethylene terepthalate)	3	9
Tin (steel) cans	8	6
Aluminum cans, foil, pie plates	8	15
Glass	39	20
Aseptic (milk cartons)	1	1
Nonacceptable (plastic bags, etc.)	38	40
TOTAL	100	100

Contamination

Contaminated bags were evident in the Folsom blue bag program. Some blue bags were recovered on the tipping floor which had obviously been used as garbage bags by households. Other blue bags were recovered which appeared to have been used for recyclables, but which had also been used for garbage.

As is indicated in the previous table characterizing the bags, there was also evidence that households were placing materials which were not desired in the bags. This may be a disadvantage of a program accepting a wide range of recyclable materials; residents believe that just about anything can be collected and place them in the bag. This may have been a particular factor in the recyclable containers bag.

Contamination might be critical for programs other than the CRRF; extensive processing to remove contaminants might be prohibitive both for costs and operations. But because of the labor afforded by the CRRF program, contamination may not be a significant detriment to the blue-bag program. Blue bags which are obviously mixed waste can be placed directly on the primary sorting line without impacting operations. All other bagged materials are directed to the secondary line. The sort into market grades at the secondary line also acts as a negative sort of contaminants, which fall off the end of the line.

CRRF blue bag compared with typical "three-bin" curbside

The weight-per-household set-out figure in the table above begins to point to some significant contrasts between the "blue bag" results and typical "three-bin" curbside recycling programs. While participation in the blue bag program lags behind three-bin systems, the amount put out by participating homes is significantly higher.

The "three-bin" curbside program utilizes separate containers for recyclables, collected by a separate truck. Further processing of the material is typically required. A narrow range of materials-- bottles, cans, and newspapers-- is typically collected.

The following table compares participation and set-outs between the Folsom "blue bag" results and the figures from the City of Sacramento and County of Sacramento, both of which use the three-bin curbside recycling program. Varied results between the three-bin programs are likely due to slight differences in the materials collected (the County collects cardboard); the practices promoted (the City asks residents to set out containers only when full); and demographics (County demographics would more likely indicate higher participation response).

Table 26.

"BLUE BAG" VS. "THREE BIN" COLLECTION OF RECYCLABLES

CRITERIA	FOLSOM BLUE BAG	SACRAMENTO CO.	SACRAMENTO CITY
Participation	17%	40%	25%
Set out pounds	38	18	20
Lbs./1,000 households	6460	7200	5000
Contamination	Yes	Minor	Minor

Field focus analysis

A field focus analysis was performed to assess the City of Folsom's source separation programs conducted in association with the CRRF. Participants in the analysis, held August 19, 1993, at the CRRF Learning Lab at the facility site, included the CRRF plant manager, materials recovery superintendent, PIA waste management division officials, City operations personnel and the project consultant.

The field focus analysis essentially features a structured review of data acquired and experience gained in implementation. Expertise and experience are applied to analyzing the results and recommending alternatives based on the analysis.

Format and objectives

The objective of the field focus analysis was to collectively review the source separation demonstration programs conducted by the City. The analysis of source-separation programs was conducted pursuant to an interagency agreement between PIA and the California Integrated Waste Management Board (CIWMB).

Special emphasis was placed on programs which would benefit the anaerobic composting operations to be conducted at the CRRF. In particular, source-separation programs were assessed for their contribution to the quantity and quality of materials suitable as organic feedstock for the anaerobic process.

Focus was also placed on the implications of the source separation programs to the operations of a CRRF facility. Such implications included facility throughput improvements and integration of clean materials into the facility processes.

The format used in the analysis followed a simple three-step process, used to analyze each of the subjects and programs addressed:

- Results, a brief presentation of the preliminary results of the demonstration.
- Analysis, including observations on the demonstration programs from the focus group.
- Recommendations, based on results and analysis.

The recommendations were largely general and informal, made in the context of the discussion of results and analysis. Any significant changes, expansions or new activities which needed further evaluation were identified for further discussion or action. Following are the subjects associated with the demonstration programs which were addressed in the focus analysis.

Education

Results

Education was largely focused on the 325-home demonstration area conducted for the residential cocollection program. The intensive door-to-door effort included distribution of bags and information to residents. A block leader program of 56 volunteers citywide was developed by the City. About eight of the block leaders were used in the demonstration source-separation route neighborhoods to assist with education and followup contact.

Several prominent articles were featured in the local newspaper, well-timed with the introduction of the program and featuring progress at the CRRF. Several City homeowners associations have received presentations about the CRRF program. Schools and other groups have also received presentations.

A survey of 75 homes (roughly a quarter of the demonstration households) was sent out and about 25 responses (about 7 percent of households) returned. The responses indicated that homes found using the bags difficult. None of responses rated the program easy; most described it as difficult.

Analysis

City staff noted that education used for promotion of the residential recycling demonstration program effectively reached residents, but might be difficult to conduct on a Citywide basis. City recycling staff noted that a month minimum was necessary to conduct the education in the demonstration area. At the rate of one month per 325 homes, it would take more than two years to reach all 8,000 City of Folsom homes.

Despite good publicity in the local newspaper, it was suggested that general awareness of the CRRF program, its goals and related City programs was very low. This was cited as a potential problem in obtaining public support for the program in general and participation in source-separation programs in particular.

Confusion and lack of public awareness were identified as barriers to the CRRF program and source separation programs related to it. The focus group discussed at length the importance of public participation in recycling. Participants were concerned in particular about "hard-core" recycling supporters, those adamant about having the opportunity to source-separate their recyclables. Estimates of the percentage of such recycling supporters in Folsom ranged from 6 percent to 33 percent.

Because residents saw no tangible results in separating materials, it was speculated, they might believe that no recycling is being done. Focus group participants differed about how far efforts should be undertaken to overcome such an impression. Much of the discussion inevitably generated toward the nature of the source-separation programs which would be used and their impression on the public's awareness of recycling.

Recommendations

Recommendations on education were discussed for the following two general areas:

- Program-related education. This includes information directed to residents on how to participate in programs such as the co-collection of recyclables (bag program).

- General education. This education is directed to the general public, making them more aware of City recycling activities, including the CRRF.

The type of program determines education, according to the field focus participants. Discussion on program education continually referenced the nature of the City's programs and whether residents could understand how to use them. This was suggested as being a problem with a unique program. Other communities using traditional "three-bin" curbside recycling have the advantage of familiarity; residents from one community to the next recognize the "three-bin" program and how to participate.

Field focus participants elected to defer recommendations on program education to the discussion on the City's actual demonstration programs. Determination of program features should be integrated with accompanying education. The block leader program, however, was strongly recommended as a continuing cornerstone of neighborhood program promotion.

Field focus participants had many recommendations on improvements to the Citywide general-education effort. PIA personnel suggested development of a video for viewing at the facility and for use by the City for presentations. Development of a comprehensive Citywide education program was suggested, using news articles, awards and any other tools to increase general understanding of the existence of the City of Folsom's participation in the CRRF and its other programs.

Residential co-collection (bag program)

Results

The residential bag program results were obtained from actual counts of participation, from the demonstration program survey and from quantification of collected materials. The field focus brought much more information on the results of the program.

Participation in the program could generally be described as starting out strong and dropping off sharply by the end of the three-month demonstration period. The high point for participation is best reflected in the results found on the tipping floor for the June 21 demonstration tip, when blue bag separated materials accounted for roughly half the materials pulled from the tip floor that day, and accounted for almost 75 percent of the recyclable materials from the floor (after the exclusion of yardwaste, bulky nonrecyclables, etc.). The low point for the participation came in late August, when only about a half dozen bags were found in the typical 10-ton tip.

According to City recycling officials, mixed paper recyclables were of high quality and easy to incorporate into CRRF processing. Participation in mixed recyclable container bagging was not as great. Yardwaste received bagged, according to facility observers, was a large part of the material pulled from the tipping floor: usually half of the tipping floor diversion, or between 5 and 10 percent of the total amount received in a load. However, most, if not all, would likely be bagged regardless of the City's source separation program, it was concluded. Little, if any, food waste was being included in the organics bag.

Analysis

Several significant obstacles to the cocollection program were discussed. Participation was a concern. Several reasons were suggested: residents may have been confused by the large number of materials to be recycled; bag use may have been inconvenient; the "invisibility" of the program and lack of peer pressure may have discouraged residents; residents may have been unwilling to purchase bags, or unaware of how to, after free, distributed bags were exhausted.

It was also observed that facility operations tended to disregard the bags as their number decreased; they were thrown in with materials up the primary line like any other plastic bag, defeating the purpose of diverting the bags directly to secondary sorting.

Significant discussion occurred concerning the value or need to source separate materials. Some field focus participants suggested that residents would require separate containers for recyclables. Others felt that this was an unnecessary cost, incurred to provide source separation just to those who otherwise would not believe they are recycling. Separate containers and vehicles could be avoided by utilizing other options such as dropoff recycling opportunities, it was suggested.

Other discussion involved how the different bags were used to collect the recyclables. It was pointed out that few residents used the clear bags for yardwaste, preferring trash bags that can be purchased at many retail locations. The separation of materials between the paper and container bags was also questioned. The suggestion of a single bag was raised. Some concern was expressed concerning contamination of paper by glass and yardwaste.

Recommendations

Several recommendations were suggested to improve the convenience and efficiency of the residential cocollection program. Suggestions made about yardwaste are discussed in the following section. Materials were addressed often in the recommendations. Food waste, it was suggested, should not be emphasized in the residential source separation program; it was a much smaller proportion of residential versus commercial waste and residents did not seem to include it with the yardwaste.

Changing the number of bags used was one suggestion to improve the demonstration program; residents could be educated to use two bags, one for yardwaste, the other for paper and mixed recyclables together. Another suggestion, discussed at length, was to have residents use equipment to make bag use easier. Recommendations to improve consumer convenience included providing residents wire bag holders of various configurations or using 30-gallon garbage cans to hold the bags with twist-ons. Further discussion of containers is taken up below in the yardwaste discussion.

Several ideas were made regarding distribution of bags. In general the ideas incorporated two approaches: the City buying bags and providing them to residents versus requiring residents to buy or obtain the bags. Distributing the bags from trucks was ruled out; bags would be wasted without a basis for replenishing. Also, that approach would not account households with higher or lower participation, or other reasons for varying bag requirements.

Other recommendations arising from the field focus deemphasized source separation curbside collection, particularly collection using separate containers and vehicles. Additional vehicles, it was suggested, would congest CRRF operations. It was recommended that alternative source separation be offered to residents, such as drop-off recycling centers. This could be offered in conjunction with improved education and promotion to residents.

Yardwaste separation

Results

Yardwaste became a concern early in the demonstration program. During the spring inauguration of the demonstration program, the wastestream of the demonstration collection area was analyzed. Characterization of the 325-home route reflected what was seen on the CRRF tipping floor; as much as 45 percent of the residential waste was yardwaste, much of it grass clipping fines.

Yardwaste evident in the wastestream dropped off considerably into the summer, as grass growing slowed down. However, it remained a large percentage of accepted materials, commercial as well as residential. The residential cocollection "bag program" was the primary City effort to separate yardwaste.

As suggested above, bagged yardwaste separated on the tipping floor represented a large percentage of the material accepted. However, field focus participants suggested, as did other analysis, that little of the bagged yardwaste was associated with the source separation demonstrations. Residents were bagging yardwaste as an already common practice, amounting to as much as a quarter of the yardwaste received from homes.

Analysis

Source-separated collection of yardwaste through residential cocollection entailed the same barriers discussed in the section above on cocollect: distribution of bags, low resident participation and so forth. Field focus participants added several further observations about yardwaste.

Considerable uncertainty was expressed about how yardwaste effected CRRF operations. A major issue for future evaluation is the impact of grass on marketability of separated recyclable materials, such as cardboard and other paper. Brokers examining the recyclables have observed the presence of grass in baled material. However, it is not known whether, and to what degree, it may impact sales and sales values.

Operations impacts were not found to be particularly serious. Grass was not found to seriously impair the ability to sort materials on the picking line, according to CRRF operations personnel. Grass clippings were associated with earlier conveyor belt mechanical problems; however, improvements to the belt mechanics have eliminated such problems.

While many residents are already bagging yardwaste, it was uncertain how other residents would respond to encouragement to bag their yardwaste for cocollection. Separate collection of the yardwaste was suggested. Several options were collected by City recycling staff and presented for the field focus. These in cost from $5,000 for continued cocollection with minimal advertising, to separate collection of yardwaste, estimated at more than a million dollars if separate containers were provided all City residences.

The field focus participants recommended that the seasonality of yardwaste be more carefully considered, particularly prior to implementing any large-scale efforts.

Wet/dry commercial

Results

Because of the site-by-site effort required, commercial separation results were largely limited to the separate collection of cardboard. This provided operational experience valuable to expanding the program. Special containers manufactured for the separate collection proved well suited to cardboard and should be suitable for other dry materials. Routing to collect the materials has been successfully incorporated into CRRF operations.

The demonstration of commercial separation also allowed the City and CRRF operations understand better the nature of commercially generated materials, particularly the variations which can occur between accounts. CRRF operations have become familiar during the demonstration with the routing of commercial collection. City staff, through waste surveys at major generators around the City, has developed information on the nature of individual generators.

Analysis

Field focus participants stressed the success of separated cardboard collection as a basis for expansion of commercial recycling efforts. They pointed to City collection of all commercial waste as a major asset to recycling that fraction of the wastestream. City staff noted that a primary limitation on commercial source separation was the demands on the City's single front-loading truck.

Recommendations

Two elements of improving source-separated commercial recyclables were cited by participants. The first was to identify loads for their level of contamination or their level of recyclables. The second aspect recommended was to provide financial incentives to participate in source separation at commercial sites.

City staff noted that recent rate increases have not provided opportunities for businesses and institutions to reduce their waste, and thus their collection costs. An exception to this is the City's cardboard collection program, which allows businesses to have cardboard collected free, eliminating the business's cost of cardboard collection.

Providing programs for businesses to recycle larger portions of currently disposed waste may ease the impact of increased garbage collection rates for City businesses. Such programs can include providing businesses with City collection of dry and wet material. However, co-collection of bagged commercial waste may not provide such source diversion rate-savings because it is collected with the mixed waste.

The existing demands on the City's front loading vehicles restrict separate business container collection of recyclables. City staff suggested considering 90-gallon automated side loading of containers. The 90-gallon "toters" could be wheeled into kitchens or offices for wet or dry recyclable collection.

The other key recommendation from field focus participants was special routing of City commercial vehicles. A recommended practice, used by other similar facilities, was the classification of routes ("A," "B," "C") according to the accounts collected and their proportion of recyclables, wet waste or other wastes. For example, special routes for accounts "rich" or "poor" in recyclables might be considered, such as an early route collecting restaurant waste which could be directly disposed if other richer routes took priority.

Regardless of the wet and dry collection service offered by the City, field focus participants suggested that further incentives would be required to induce participation by commercial sites. It was noted by City representatives that commercial collection rates has recently increased. It was also noted that the dry cardboard collection service was provided free to commercial customers and that collection of waste containers at those accounts was minimized.

A formal, well-promoted program to integrate cost incentives with source separation programs for City commercial accounts was suggested. Differentiated for wet or dry recyclables collection could be adopted as soon as possible. This would best make businesses aware of savings from recycling that could offset the increased costs of waste collection. The program should be promoted extensively as soon as the City's service and recycling savings can be applied citywide.

General recommendations

A source separation program for cities which implement a Correctional Resource Recovery Facility can benefit facility operations, residents and businesses at minimal direct operational costs to the municipality. Based on the results of the Folsom demonstration project, source separation activities should consist of the following:

1. A residential program using two separate bags to collect recyclables and yardwaste.

2. A commercial recycling program based on wet/dry collection. The program should begin with a routing program coordinated with CRRF operations. A separate route for separated cardboard should be begin first, later expanded to include additional materials and separated dry accounts such as large institution generators.

3. Yardwaste programs. Major generators of yardwaste such as large institutions and landscape contractors should be targeted, particularly during the growing seasons, using special temporary collection integrated with CRRF operations.

City of Folsom recommendations

The following recommendations are made for the City of Folsom to conduct full implementation of source separation activities integrated with CRRF operations. All the recommendations included here follow the programs selected in the City's Source Reduction and Recycling Element (SRRE), adopted by the City Council in November of 1991.

Residential source separation

The City should expand the blue bag program citywide after adopting an implementation schedule coordinated with the implementation of CRRF operations. The citywide residential program should include the following features:

A citywide education program.

A citywide education program should be the first step in implementing residential source separation citywide. The citywide education effort should begin regardless of the schedule for phasing in program-specific education, bag distribution or CRRF operations. Demonstration results indicate that extra effort is required to inform residents of their City's recycling efforts.

The citywide education effort should emphasize the comprehensive City recycling effort, including efforts at source reduction such as backyard composting. The program should inform residents on how recyclables placed in their containers are processed by the CRRF for recycling.

Education keyed to participation in the bag program should show residents how other homes are using the bags to recycle. Program education should continuously inform residents which recyclables go in the blue bag and which do not. Features of the education program might include:

- Production of a video on the CRRF and City source separation for viewing by resident associations, service groups and other gatherings.

- Continued block leader activities. These activities might be coordinated with distribution of recycling bags.
- A scheduled series of public notices, news releases and public appearances on City programs. These should be established on a calendar year to anticipate seasonal activities.
- Regular public feedback, including communication and feedback from informal advisors from the residential, commercial and other serviced generators of waste.
- Direct mail notices or newsletter. The City does not have the capability to insert notices with utility bills.
- Direct mail to commercial accounts informing them on recycling services and potential savings.
- Waste surveys of commercial locations.

Modification to two bags only; one for all recyclables; the other for yardwaste.

Under this modification residents would use only one blue bag for all recyclables other than yardwaste. Yardwaste separation would be conducted by aggressively educating residents to use any type of plastic bag to separate yardwaste; "just bag it." This change, eliminating two of the bags used in the demonstration, would provide the following improvements:

- Simplify household participation and education.
- Improve CRRF tipping floor separation of the bags and the need for debagging.
- Increase the residents' ability to obtain bags by reducing the number needed. This might also allow the City to help provide bags to residents.
- Build upon residents' existing use of plastic bags for yardwaste.

A single bag of recyclables makes best use of the labor on the CRRF secondary sorting line, where a range of material types can be sorted. With fewer bags needed by residents, the City can consider occasionally providing free bags to residents. The City may be able to encourage resident use of blue bags by obtaining discount coupons from manufacturers and distributing them as promotions.

A program to monitor yardwaste participation.

Because of the major benefits of separating yardwaste from the wastestream, the City should take steps to assure success in this area. To do so, a program to document yardwaste separation should be established. Samples could be recorded at the CRRF tipping floor of bags; characterization study can be performed and many other techniques are available to do this.

The monitoring program should provide "triggers" for implementing separate collection of yardwaste and mandatory separation, which are discussed following. Currently about 10 percent of yardwaste material accepted by the CRRF is already separated in bags. The City should set a standard to achieve, within the near term, separation of 50-75 percent of the yardwaste accepted. The monitoring program would evaluate progress toward these levels.

Contingencies for separate bagged yardwaste collection

The City should develop a program for separately collecting residential yardwaste. The separation program should be considered a contingency should co-collection of yardwaste bags in waste containers fail to achieve progress toward 50-75 percent separation levels.

Several options for separate collection are available. Separate collection of yardwaste bags would be a simple program which would save the expense of additional containers. Such a program would allow residents to place bagged yardwaste at the curb.

A standard, rear-loading compactor truck, such as the City already has available, could be used to collect the materials. A two-person crew would be required. Such a program would allow for seasonal flexibility; the collection could be limited to the growing seasons for yardwaste, spring and fall.

Other options for separate collection include providing residents with a separate container for yardwaste. This option is most suited to permanent, year-round routing to collect the containers. However, benefits could be realized by the ability to collect containers using automated collection vehicles; more accounts can be collected with less labor.

Contingencies for an ordinance mandating yardwaste separation from other waste

The City should set performance goals for the separation of yardwaste; it should establish a program to monitor progress toward the goals; it should consider a City ordinance requiring residents to separate yardwaste for collection as a step to achieving yardwaste separation goals.

A mandatory yardwaste separation ordinance should not be considered any more draconian than prohibiting residents from disposing tires or hot ashes in waste containers. Enforcement does not need to be extensive and education should precede any action taken for violations.

Key to the fairness of a separation ordinance is the opportunity, provided by the City, for residents to have their yardwaste collected or dropped off separate from waste. Cocollection of bagged yardwaste with the waste should be understood as meeting requirements for separation.

Commercial source separation

The City should expand, citywide, its program of separate collection of dry recyclables at commercial locations. It should also institute pilot collection of wet recyclables such as kitchen scraps. It should, in coordination with CRRF operations, adjust commercial collection routing to "high-grade" accounts, keeping paper routes separate from more putresible routes such as restaurants. Citywide dry recyclables collection should be instituted as soon as possible, but after preferential rates are considered for those businesses separating recyclables.

Differential rate structure implemented for waste and recyclables.

The City, on a pilot basis, is collecting the dry cardboard containers from commercial accounts for free. The rate base supporting City collection services should be evaluated for its ability to expand this service Citywide at no cost to commercial businesses.

Dry recyclables collection would give many City businesses the opportunity to mitigate their solid waste collection costs. However, businesses' success in reducing their waste results in corresponding revenue losses to the City.

The City operates its solid waste services on an enterprise basis. Total operating costs must be met from total service fees collected. A free collection service must be financed in the rate base or from other revenues. Revenues from the sale of recyclable materials collected would be unlikely to completely meet operating costs, but might offset them.

The City should determine at the earliest possible time how these rate issues can be resolved. In the process, it should consider that garbage rates can provide a significant movitation to business recycling participation.

Expanded cardboard collection accounts.

The modified containers developed by the City for cardboard collection have proven successful. The City should begin to acquire additional containers to be used at account Citywide. Requirements for vehicles and personnel should be considered as soon as possible.

It is important that an aggressive education effort be launched to inform businesses Citywide of the opportunities and benefits incurred by recycling. Should the City provide collection of recyclables at a less expensive rate than waste collection, this should be an important element of the education efforts.

Expanded separated collection of dry recyclable accounts.

In conjunction with expanded cardboard collection, the City should allow businesses to include other dry recyclables in the collection containers. Such materials might include recyclable plastics, office paper or newspaper.

Any additional materials accepted should be determined site-by-site, based upon waste surveys of the business locations conducted by the City Solid Waste Division. This would allow the City to test the feasibility of collecting materials without committing to their collection Citywide.

Pilot wet recyclable accounts instituted at larger institutions and commercial accounts.

The City should select targeted commercial and institutional accounts for collection of compostable, "wet" materials such as foodwaste. Such service should be preceded by waste surveys of the individual sites. The waste survey should be accompanied with educational information on how the generator can reduce disposal costs through recycling, composting and waste reduction.

Develop contingencies for separate collection of construction and demolition waste.

The City should design a program to provide separate collection of recyclables and compostables from construction and demolition sites. Wood waste, site brush clearings, sheet rock and other materials generated at construction and demolition sites can be handled by the CRRF.

The City has the capability to provide construction and demolition waste collection. The separation program can be integrated into this service by providing containers designated for separated materials. A method of differential rates for separated recyclables should be evaluated. This can be done with overall rate policy adjustments.

Yardwaste

The following are a couple recommended simple programs which can assist the City and the CRRF to collect clean separated yardwaste. These can provide a clean CRRF compost feedstock. Both programs provide high flexibility, easy implementation and little cost.

Pilot yardwaste drop-off program instituted.

The City should provide residents and businesses with the opportunity to drop off clean yardwaste for composting at the CRRF. This can be done using a roll-off debris box. Dropoff events can be conducted periodically and maximized for seasonal generation of yardwaste. Plenty of pre-publicity can assist residents and businesses to schedule their use of the program. The program could be seen as a valuable service to residents who might otherwise self-haul materials to the landfill or use garbage containers for yard projects which generate large volumes.

Residential yardwaste drop-bin program developed for pilot testing in spring.

This program is largely conducted by education. Residents are informed that drop bins are available at special rates if used exclusively for organic yardwastes and trimmings. Any special rates must first be determined in City rate policy. This program would be suited to residents or groups of residents conducting special yard projects, such as commonly are done in the spring or fall.

REGULATORY ISSUES

Introduction

Several regulatory issues impact the viability of CRRF anaerobic composting operations. Some such issues arise from the unprecedented nature of the process, others are entailed in the overall adjustment of regulators to the new era of widespread composting of all kinds. Other issues, such as environment impact, are generic in nature.

The Prison Industry Authority is permitting the facility as a solid waste facility under existing regulations administered by the California Integrated Waste Management Board. Regulations and statutes which apply to compost facilities operated in California are unclear. The CIWMB drafting regulations which might applied to certain composting operations.

Features of the CRRF anaerobic composting process which may be impacted by the outcome of regulations developed include the following features:

1. Waste types. Several materials are handled, but have been presorted into clean batches.
2. Nature of the process. The actual composting is conducted mostly in-vessel.
3. Application of the humus end product. Its characteristics may require special handling and marketing.
4. Project development by a state agency.

Because of the unique nature of the process, regulators are not familiar with how it should be handled. This report presents the relevance of the operation's unique aspects to permitting and regulatory compliance. An explanation of the regulatory process undertaken in the compliance of the facility is given with recommendations on how future projects may approach the task.

In addressing the regulatory issues involved with application of the humus end product, the report will detail the implications of permitting different uses. Such implications for regulatory approval may include federal land application regulatory hurdles and air emissions standards for incineration of the humus.

The paramount issue involved in this topic is the conformance of the unique technology and program engendered by the CRRF concept in an era of great regulatory uncertainty for all composting operations. The following section includes recommendations for future compliance of CRRF composting facilities.

Current regulatory environment

Many composting facilities operated in California are required to have a Solid Waste Facility Permit. This is a relatively recent statutory requirement, adopted on the heels of the landmark reforms of the 1989 California Integrated Waste Management Act.

Prior to the Integrated Waste Management Act legislation, composting activities fell into a gray area in terms of state permitting and regulatory control. Local land use controls and state water discharge compliance were in force. However, few composting operations were required to obtain a state Solid Waste Facility Permit (SWFP), and thereby fall under the compliance and enforcement regulation imposed by the CIWMB.

Growth of composting under the goals of the IWM Act to reduce landfill disposal could be anticipated. The act anticipated a sudden increase in the number of composting facilities and quantities of materials they would handle. Perhaps less anticipated was the range in types of materials which might be composted. The requirement of a Solid Waste Facility Permit would expected to provide state assurance that many new and large composting facilities would not create environmental detriment equivalent to landfills.

The legislation establishing state permitting and regulatory control over solid waste facilities is not specific to the type of solid waste facility. At the time, the solid waste facility permit, as it still exists in CIWMB regulations, largely reflected its long-standing purpose of governing the creation and operation of solid waste landfills. Extensive assurance is required, prior to accepting materials, that public health and safety can be assured at the facility.

The basic SWFP still remains as it was when its primary function was landfill regulation. However, a large number of new solid waste facilities brought before the CIWMB are diversion-related facilities, such as material recovery operations and composting facilities, often operated in conjunction with solid waste transfer operations.

The Solid Waste Facility Permit

Regulations governing the application for and issuance of SWFPs is found in California Code of Regulations, Title 14, Chapter 3.1 "Composting Facilities Permitting Procedures and Enforcement;" Chapter 5, Article 3.1 "Application for Solid Waste Facility Permits;" and Article 3.2 "Reports of Facility Information." Related matters of modification, suspension or revocation of a permit are found in Article 4 "Enforcement by Enforcement Agency and Enforcement by Board."

In general, the SWFP is received through an application to the Local Enforcement Agency, a local government agency, often the environmental management agency of the local County. The SWFP application package requires an application form, a "Report of Facility Information," and a compilation of other approvals and documents as required either specifically by regulation, by the local enforcement agency or other agencies. The Local Enforcement Agency deems the application complete and the description of designs, operations and other features sufficient to meet the requirement of Title 14, Section 18201:

> *(b) The application package shall require that information be supplied in adequate detail to permit thorough evaluation of the environmental effects of the facility and to permit estimation of the likelihood that the facility will be able to conform to the standards over the useful economic life of the facility.*

Green composting facilities

The CIWMB has attempted to tailor the SWFP to specific types of facilities. The permit requirements for green composting facilities were adopted in the summer of 1993 after lengthy hearing and many iterations. The green waste facility permit is a subclassification of the SWFP. A "report of green composting site information" was developed for the permit application package.

The green composting regulations apply only to facilities which qualify as receiving only material such as yard-waste, grass trimmings and similar organic materials. Regulation specifies that the material received at the green composting facility must have been source separated "at their source of generation." (Section 17853)

The Report of Facility Information for green waste must include most of the design and operations detail required of any other facility. Additional detail specific to composting, such as depth to ground water, is also added. Pathogen reduction must also be verified.

The following table compares requirements for solid waste facilities with those of green composting facilities. The table is not intended to be all inclusive, but to illustrate the different permitting and operating issues which arise. These features are subject to as CIWMB regulations continue to be modified for composting facilities.

Table 27.

PERMIT REQUIREMENTS

REQUIREMENT	SOLID WASTE FACILITY	GREEN COMPOSTING FACILITY
Exemptions	None	No permit required below 300 tons on-site.
Acceptable material	Solid waste, conditions are attached for many special wastes such as contaminated soil.	"Green" organic waste as defined, source separated at site of generation.
Feedstock amendments	Not applicable.	Up to 20 percent, as defined.
CEQA environmental documentation	Yes.	Yes.
Leachate collection	Yes.	Yes.
Gas control	Yes.	No.
Operations standards	Yes.	Yes.
Full application requirements	Yes.	Yes.
Full inspection and enforcement	Yes.	Yes.

The green waste composting operations standards also include extensive requirements relating to leachate management and permeability of the surface used for composting.

End-product performance standards

The regulations adopted July 15, 1993 for green waste composting include performance standards relating to the compost end product. The operator must ensure that the end-products are innocuous and free of sharp-edged particles that could endanger human health and safety.

The end-products of a composting operation can not contain constituent concentrations in excess of the Soluble Threshold limit Concentration or Total Threshold Limit Concentration specified in state and federal codes. Any material that exceeds these limits is classified hazardous waste.

Maximum metal concentrations, conforming with those of 40 Code of Federal Regulations Part 503.13(b)(3) are cited in the state performance standards. Pathogen reduction standards are also cited. These are expressed in terms of the duration and degree of temperatures maintained in the composting process. Generally a temperature of 53-55 degrees Celsius must be maintained for three to five days, depending on the process. Windrows must be turned on a regular basis.

Compost end product are required to follow a monitoring program. The monitoring program requires that at least one sample be analyzed for every 5,000 cubic yards of green compost produced. The samples will be analyzed for the constituents and pathogens identified in the performance standards. Temperatures of the compost must be recorded to show compliance with pathogen reduction. Analysis must be conducted at approved laboratories. More frequent monitoring can be required by enforcement agencies.

Compost facility operators are required to submit reports of all analyses, certification, and documentation for such performance standards as pathogen reduction and leachate.

CRRF Composting

The CRRF anaerobic composting process has several features in common with other process, but the combination of its features makes it unique. The CRRF process is similar to most in-vessel composting in its general operation-- its contents are isolated from the outside environment. It is similar to green waste composting operations in that it uses combinations of relatively homogenous feedstocks.

The difference in CRRF composting is that the source of its feedstock is derived from the labor intensive use of state penal inmate labor to produce the feedstock from sorted municipal solid waste. This "post-waste" feedstock, separated at the CRRF, is then neither source-separated, nor still mixed solid waste. The post-waste feedstock characteristics can be readily certified.

The high solids anaerobic composting process developed by UC Davis and PIA is also unique. Very little in-vessel anaerobic composting is now conducted on the scale necessary for a municipal wastestream. Most anaerobic composting is currently in use for sewage treatment. These operations typically feature a "slurry" process with liquid comprising 90 percent or more of the material in relation to solids.

The CRRF anaerobic process features a higher proportion of solids to liquids. The Folsom anaerobic digester will handle solid contents in the range of 20-25 percent of the total weight. This has implications to many aspects of the process, including material feeding, water use and the nature of the humus byproduct.

The characteristics of the byproduct is important for several reasons: its water content is a factor in water discharge permit requirements; composition of metals and other substances must meet permitted standards; the state of humification could determine whether the humus byproduct is still "composting," a determination important for facility permitting issues.

Difference and similarities between the CRRF anaerobic composting operation and other composting may determine how it fits into the regulatory environment for solid waste facilities.

The following is a comparison of the features of the CRRF anaerobic composting operation with "green" composting facilities, aerobic composting typically conducted in pile or windrows for source-separated yardwaste.

Table 28.

COMPARISON OF FEATURES

FEATURE	CRRF ANAEROBIC FACILITY	GREEN COMPOSTING FACILITY
Feedstock	Separated foodwaste, yardwaste, wood and paper.	Yardwaste.
Size (material on-site)	26 tons of organic waste each day for each digester: 728 tons at one time.	Varies within broad range. Permanent exemption for facilities with less than 300 tons on-site.
Surface	Digester vessels are impermeable, including surface.	Impermeable (generally paved) surface required.
Containment	Total impermeable vessel enclosure.	None.
Odor control	Contained in vessel and collected by gas collection system.	Odors when not properly operated.
Water discharge	None.	Surface and rain water require collection system.
Byproduct	Humus may need further drying and humification.	Humus. May vary according to operation and feedstock.
Product performance standards	Meets green waste state standards.	Must meed state standards in order to operate.
Gas collection system	Yes. With controls and flare backup.	No.

Feedstock as permitting criteria

The California Integrated Waste Management Board is reformulating the permitting and enforcement requirements for composting facilities. The CIWMB has held policy hearings on a permitting approach specific to facility types. Under such an approach, solid waste facility permits might would vary according to type of facility. The green waste composting facility permit is an example of this approach.

Regulations are being drafted by CIWMB for composting facilities other than green waste facilities. Following the approach taken for green composting facility regulations and based on CIWMB hearings held, feedstock type has been considered as a basis for determining operations standards and associated permitting.

Such an approach might assign composting facilities to one of three classifications, or tiers, for compost facility permitting. Examples might include the following:

- Food waste. With separate consideration for vegetal and animal food waste. This category feature operating standards and permitting requirements which closely resemble those developed for green, yardwaste composting facilities.

- Sludge. Alone or in combination with other materials. Permitting of sludge would likely adhere closely to federal regulations for threshold constituents of heavy metals and other substances. Stringency of the regulations would likely be the equivalent of requirements made for solid waste facilities.

- Solid waste. Any material which has entered the solid waste stream would be categorized as falling within this category for the purposes of permitting and enforcement of composting facilities. This category would likely require the most stringent standards of operations to be permitted.

CRRF composting would likely fall within the last category, solid waste, for operating standards and permitting requirements. Feedstock for CRRF composting would be derived in part or in whole from the separation of mixed waste. CIWMB staff, in formulating early drafts of compost permitting regulations, make clear the fundamental distinction between source-separated feedstock and mixed waste. CRRF compost feedstock, although separated into homogenous material types, would be mixed waste derived.

Several issues may complication the categorization of the CRRF composting operations according to possible tiering criteria. These issues include the following:

- The operation does not handle solid waste. Material has been separated from the wastestream and may be used as composting feedstock, or it could be destined for traditional recycling markets. Other compost materials will have been source separated, such as bagged yard waste recovered on the CRRF tipping floor.

- Storage of the materials. This "in-between" stage of the materials illustrates difficulty in regulating the potential feedstocks. Newspaper, for example, may be destined for either the recycling truck or the digestion vessel, but stored, indistinguishably, in the same baled piles. Food waste compost feedstock, on the other hand, would have different storage considerations.

- The facility may be considered an energy facility, as well as or even rather than a composting facility. The composted residue could be regarded as a by-product of the energy generation in much the same way that ash is regarded when produced from cogeneration operations.

Demonstration permitting

The Folsom CRRF facility offers an important example of demonstration permitting for a solid waste facility. The CRRF obtained a demonstration approval under state regulations adminstered by the Local Enforcement Agency. The facility's experience under this demonstration status provides a model for "backloaded" permitting of waste diversion facilities.

This temporary, conditional approach to permitting allows the facility operator to begin operations and demonstrate health and safety to local enforcement agencies without receiving full permitting status. This can provide empirical assurance of safe and viable operations. The current solid waste facility permitting process can typically only provide this assurance on paper.

The demonstration permit is provided under Section 18215 (CCR Title 14) of state regulations. Following is the language of 18215.(a), which pertains to the criteria which qualifying facilities must meet before being granted an exemption:

(a) After a public hearing the enforcement agency may grant an exemption from the requirement that a solid waste facility obtain a permit. Such an exemption may be granted if the facility falls within one of the classifications which may be exempted and all of the following findings are made:

(1) The exemption is not against the public interest.
(2) the quantity of solid waste is insignificant.
(3) The nature of the solid wastes poses no significant threat to health, safety, or the environment.

There are eight classifications referred to in 18215.(a) which qualify for exemption upon meeting the three criteria. For the most part, the classifications pertain to very unique facilities for such materials as mining tailings or agricultural wastes. The classification which pertains to PIA's CRRF facility is 18215(b)(6), which reads:

(6) Resource Recovery facilities intended only for demonstration purposes and not for profit.

Subsection 18215 (c) states that the enforcement agency must forward any exemption to the CIWMB within seven days after the decision is granted.

Demonstration permit application

PIA initiated the request for demonstration permit exemption, submitting the request to the Local Enforcement Agency, Sacramento County Department of Environmental Management.[1] The January 19, 1993 request included a description of the project site, operations and facilities and stated that PIA would conduct the demonstration activities according to any stipulations made by the LEA.

The LEA was already in receipt of the application for solid waste facility permits for both the material recovery facility and the composting operations. Review of these documents by the LEA had been undertaken for nearly a year when the request for demonstration permit was made.

[1] The CRRF was subject to all state solid waste facility permit requirements and underwent the same permitting process as other material recovery facilities. Any future PIA resource recovery facility is also required to complete solid waste facility permitting, when applicable.

LEA approval of the solid waste facility permits was given shortly after the granting of the demonstration exemption. The SWFP applications were submitted in draft to the CIWMB. The draft remained under CIWMB review for the initial demonstration period of about six months.

The only criteria which presented an obstacle to the LEA's granting of exemption was 18215.(a)(2), that the quantity of solid waste be "insignificant." The LEA was reticent to assume a definition for the term "insignificant." CIWMB permitting and enforcement staff were unable to provide precedent or standards for the term's application to a solid waste facility recovery waste for demonstration purposes.

Ultimately, the standard inherent in subsection 18215(a)(3) was applied to the term "insignificant"; the quantity of waste, like the nature of the waste, should "pose no significant threat to health, safety, or the environment." The amount is "insignificant" if the facility and its operations can process the quantity without "significant threat."

In order to provide the assurance of no significant threat, PIA was requested to submit an addendum to the "Request for Demonstration Permit." This addendum specified that the facility would accept material at levels which assured safe and viable CRRF operation. In practice, this meant accepting increasing amounts in very gradual phases.

Several other meetings with LEA staff took place to resolve questions or concerns about the demonstration operations. Concerns addressed included the capability to transport, or "backhaul," residue to the landfill; storage of materials; and handling and storage of hazardous waste.

When all concerns were addressed, the public hearing required by section 18215 was scheduled. The regulations do not specify public notice requirements for the public hearing. After an opinion from County Counsel, the LEA adopted a notification policy for section 18215 exemption that includes a 30-day public notice period, including newspaper publication, and mailed notice to adjacent property owners and related agencies.

The public hearing to grant the demonstration permit exemption was held April 29, 1993. No comment was made from public. After the hearing the LEA granted the demonstration permit exemption with several conditions.

Demonstration permit implementation

Close interaction with regulators took place in conjunction with each phase of demonstration operations. Notice and approval were given with each increase in volume accepted. Several regulating authorities were able to participate by this demonstration process. In addition to the LEA's permitting personnel, LEA enforcement and inspection staff began regular inspections. Other health and safety officials, such as the fire marshall, were able not only to observe, but to make recommendations, which could be incorporated before the facility achieved full operations and final permit status.

CRRF demonstration provided a unique and valuable process for both PIA and regulators. Inherent in the concept of the demonstration was providing evidence of safe and viable operations. The demonstration phases entailed all the challenges of commissioning: increasing tonnage, equipment implementation, personnel training. Regulators such as the LEA can acquire first hand experience with material recovery facilities accepting solid waste. The demonstration period allowed issues to be identified by the LEA and addressed by the operator while proceeding with the commissioning of the facility in controlled, manageable stages.

As the demonstration progressed to accept greater daily quantities of waste, both PIA and regulators were able to make adjustments which assured both safety and viable operation. Following are several examples of where this process was valuable:

- Worker health and safety. This is an area which continues to be unknown or unexperienced for many regulators, despite the frequently mentioned increase in regulator interest. The CRRF LEA was able to see the working environment first-hand. Industrial safety personnel form Cal-OSHA and CIWMB were brought to the facility by the LEA. Their feedback allowed PIA to assure health and safety at the facility.

- Process quantification. The emphasis on documenting the demonstration process has provided firm evidence of material throughput, by process, quantities and types. This will provide assurance to the LEA and other regulators of concerns such as storage, compost feedstock and ability to "backhaul" residue to landfill.

- Hazardous and special waste. This is a constant concern of regulators where mixed waste is accepted and separated. Possible quantities and types in the wastestream are an uncertainty. The ability of the CRRF to separate more of the wastestream than has been previously achieved means that hazardous and special volumes will be found if they exist in the accepted waste.

  The actual experience and documentation of the evidence of these wastes was produced by the demonstration. Working with regulators, PIA improved its procedures for dealing with the materials. Some concerns, such as medical waste, which were an initial concern, were reduced as experience showed a low incidence and provided a better staff understanding of special wastes.

HIGH SOLIDS ANAEROBIC COMPOSTING OPERATIONS GUIDE

Introduction

As important as the design of the CRRF anaerobic digestion vessels is their operation. Feedstock mixing and preparation, loading of the vessels, monitoring and other material processing will all be done by state inmate workers.

Supervision of the operations will be conducted by trained PIA personnel, experienced with composting. Still, specific operating experience of high-solids, anaerobic technology is not possible. No other operation, on such a scale, exists.

To assist PIA in the effective and successful operation of the digesters, a guide was prepared by the Department of Civil and Environmental Engineering at the University of California, Davis (UCD). The specific objectives of this guide are:

1. To describe the importance of nutrients in the anaerobic digestion process.
2. To provide a procedures manual for feedstock preparation.
3. To provide analytical techniques and methodology for digester monitoring.
4. To discuss causes of abnormal digester behavior and possible actions to prevent digester failure.

Process overview

Metabolism that occurs in the absence of oxygen is called anaerobic digestion. A schematic diagram of the anaerobic digestion process is shown in Illustration 5. Conventionally, anaerobic digestion is considered to take place in three distinct, yet very closely related, phases. The three phases are:

1. Polymer breakdown phase,
2. Acid forming phase, and
3. Methane forming phase.

The three phases are distinct in that they are comprised of separate kinds of chemical reactions caused by separate types of bacteria, and they occur in sequential order.

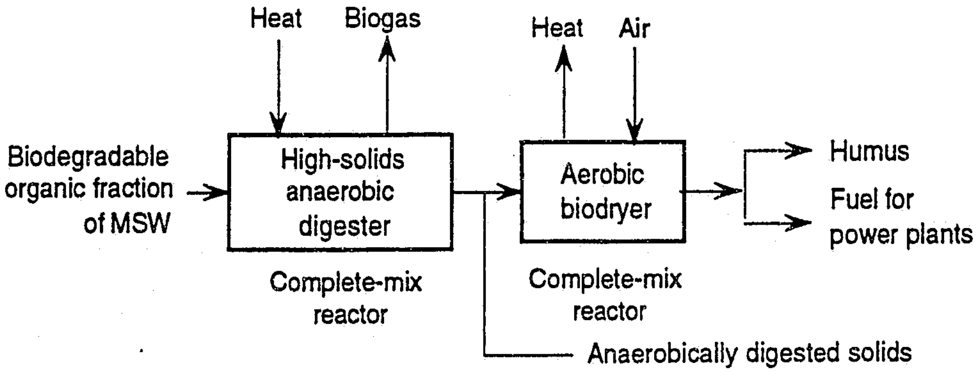


Illustration 5. The high solids anaerobic digestion process.

Complex organic compounds include particulate materials that must be hydrolyzed, in the polymer breakdown phase, into soluble compounds that can be used by acid-forming bacteria. Soluble materials are oxidized to low-molecular-weight organic acids, including acetic acid. In the methane forming phase, different bacteria convert hydrogen, carbon dioxide, acetic acid, or other compounds into biogas. The biogas produced is a mixture of methane and carbon dioxide with small amounts of other gases, including hydrogen sulfide, hydrogen, and low-molecular-weight hydrocarbons.

Biogas is combustible, with a caloric value of about 26 MJ/m3 (500 Btu/ft3), depending primarily on the concentration of methane gas. Biogas can be used as a fuel for heating or to generate electricity. However, because biogas contains so much inert carbon dioxide, it requires a larger storage volume for a given energy than other fossil fuels. The pressure required to liquefy biogas for storage is nearly 34,450 kPa (5,000 lb/in2). A stationary combustion process near the digester can minimize this problem by using the gas directly, as it is produced.

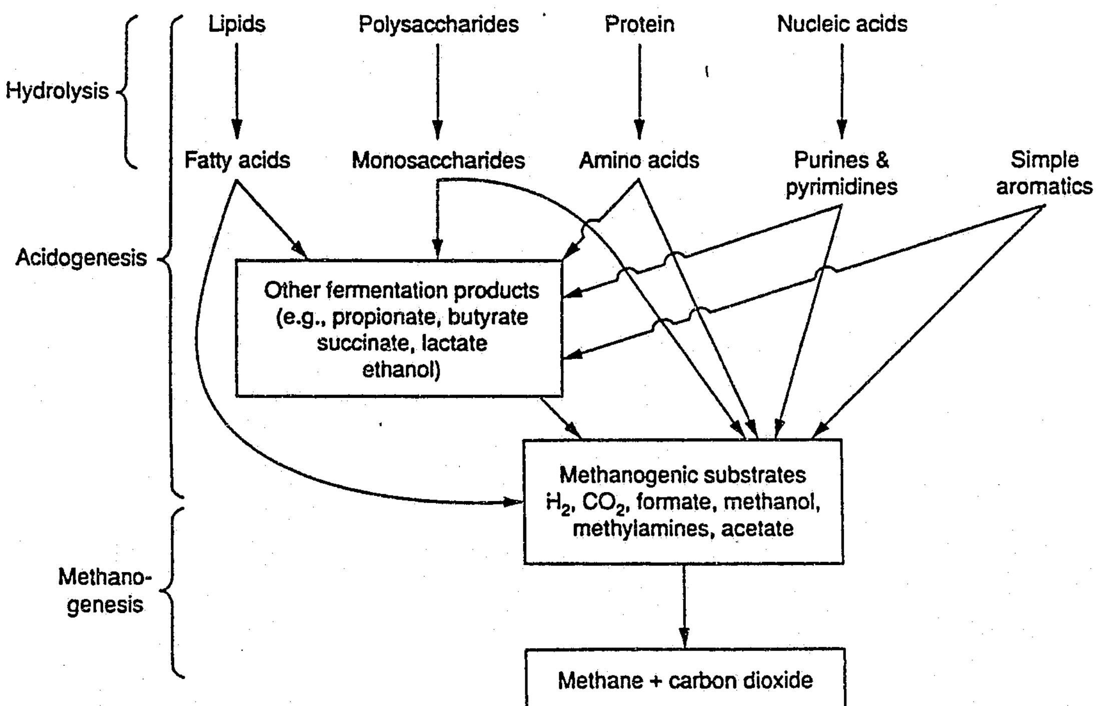


Illustration 6.
Stages in the production of methane and carbon dioxide from the anaerobic digestion of the biodegradable fraction of MSW (from Holland, et al., 1987)

Nutrient requirements

To operate the high-solids anaerobic digestion process at the commercial level, attention must be focused on process stability. Successful operational parameters have been established for the high-solids process in recent feasibility studies conducted at the University of California at Davis (final report submitted to PIA, Kayhanian et al., 1991). However, in the anaerobic digestion of municipal solid waste (MSW), bacterial nutritional requirements have often been overlooked.

Nutritional deficiencies may result in reactor instability and incomplete bioconversion of the organic substrates. When the anaerobic digestion process is applied to MSW, bacterial nutritional requirements must be addressed, and nutrient supplementation may be required (Rivard et al, 1979).

Methanogenic bacteria have a variety of mineral nutrient requirements for robust growth (Speece and McCarty, 1964; Speece and Parkins,1985). For proper bacterial metabolism a variety of nutrients must be present in the substrate. The nutrient requirements for anaerobic bacteria can generally be categorized as macro- and micro-nutrient. For a stable anaerobic digestion process, these nutrients must be present in the substrate in the correct ratios and concentrations.

Based on studies conducted at UC Davis, it was found typical wastestream organics used as a feedstock for anaerobic digestion process is deficient in many essential nutrients. If a feedstock is deficient in a certain nutrients, supplementary nutrients must be added to stimulate the digestion process. The values reported in Table 30 are based on three years of experience at UC Davis high-solids biogasification project.

Table 29.

NUTRIENT CONCENTRATIONS REQUIRED FOR THE ANAEROBIC CONVERSION OF MSW

NUTRIENT	UNIT	RANGE (1)	TYPICAL (1)
C/N (2)		20-30	25
C/P		150-300	180
C/K		40-100	70
Co	ppm	<1-5	2
Fe	ppm	100-5000	1000
Mo	ppm	<1-5	2
Ni	ppm	5-20	10
Se	ppm	0-0.05	0.03
W	ppm	0.05-1	0.1

(1) Average value (dry basis)
(2) C/N, C/P, and C/K ratios based on biodegradable organic carbon, total nitrogen, phosphorus, and potassium.

Feedstock preparation

A general waste characterization study was performed for the City of Folsom by the Sacramento consulting firm California Resources (1992). This characterization study, conducted in accordance with state law AB 939, included the wastes generated by the City of Folsom from residential, commercial, and other (primarily prison and park) sources. Data from this study are used to illustrate a procedure for feedstock preparation. The feedstock preparation topics presented in this report are:

1. Composition of Folsom MSW,
2. Biodegradable organic fraction of MSW as a feedstock,
3. Importance of C/N ratio for feedstock preparation, and
4. Procedures for daily feedstock preparation.

The composition of the Folsom MSW was characterized using the following eight waste categories: (1) paper, (2) plastics, (3) glass, (4) metals, (5) yard waste, (6) food waste, (7) other organics, and (8) other inert wastes. The results of the Folsom waste composition studies, based on the above classification, are reported in the previous section on "Project Description," beginning on page 22 of this report.

Most of the organic fraction of the City of Folsom's wastestream is composed of paper, yard waste, and food waste. As shown in Table 30, the percentage of both yard and food waste increased during the summer while the paper percentage increased 11 percent in the winter. Paper, yard waste and food waste, the principal organic constituents, comprised 75 and 77.5 percent of total wastes for winter and summer seasons, respectively. An average value of 75 percent is representative.

Based on this composition, it has been estimated that, on a dry weight basis, around 42 tons of paper, nine tons of yard waste, and five tons of food waste will be recovered daily. The corresponding percentages of the total organic fraction are 75, 16, and 9 percent, respectively. These percentages will be used to prepare a digester feedstock for the Folsom resource recovery facility.

Table 30.

CITY OF FOLSOM WASTESTREAM
SEASONAL PERCENTAGE VARIATIONS

MATERIAL	WINTER (1)	SUMMER	VARIATION
Paper	45.23%	40.10%	-11.34%
Plastics	9.14%	8.20%	-10.28%
Glass	3.45%	2.50%	-27.54%
Metals	4.11%	3.10%	-24.57%
Yardwaste	18.66%	24.00%	+22.25%
Foodwaste	11.06%	13.50%	+18.07%
Other organics	4.03%	4.60%	+14.04%
Inert and other waste	4.32%	4.10%	-5.09%
TOTAL	100.00%	100.00%	

(1) Percentages are wet basis.

Biodegradable organic fraction of MSW as a feedstock

The biodegradable organic fraction is defined operationally as the fraction of organic material that can be converted to carbon dioxide and methane under optimum digester conditions in a period of 30 days. The biodegradability of the organic fraction of MSW can be estimated based on the lignin content of the materials (Chandler et al, 1980). Estimates based on bench tests are more accurate, but require much more time and equipment.

The following relationship, proposed by Chandler et al, can be used to estimate the biodegradable fraction of an organic substrate, based on the lignin content.

Equation 1.

$$\text{Biodegradable fraction} = 0.83 - (0.028) \times LC$$

where the biodegradable fraction is expressed on a percentage of volatile solids (VS) basis, LC is the lignin content of the VS, expressed as a percent of the dry weight. The lignin content of the mixed biodegradable organic fraction of MSW from Folsom is 5.5 percent. Using Equation 1 and a lignin content of 5.5 percent, the biodegradable fraction of the Folsom organic MSW is calculated to be around 68 percent of the volatile solids. The corresponding value based on total dry organic weight is 50 percent.

If the percentages of paper, yard waste, and food waste in the MSW being sorted by the Folsom facility change, the biodegradability of the feedstock will also change. The new biodegradability can be calculated based on the lignin content, or it can be estimated using the new percentages and the average values given in Table 31.

Table 31.

EST. MSW BIODEGRADEABLE FRACTION, BASED ON LIGNIN CONTENT		
COMPONENT	LIGNIN % / VOLATILE SOLIDS	PERCENT BVS (2)
Foodwastes	0.4	81.9
Newsprint	21.9	21.7
Office paper	0.4	81.9
Mixed paper (1)	5.8	66.7
Yard wastes	4.1	71.5

(1) 25 percent newsprint, 75 percent office paper
(2) Biodegradable volatile solids

Importance of C/N ratio for feedstock preparation

As indicated before, all essential nutrients are equally important for cell synthesis, growth, and metabolism when the anaerobic digestion process is used to degrade the MSW for gas recovery. The most abundant nutrients are carbon and nitrogen. For practical purposes, the C/N ratio is used as a basis for the nutrient requirements in the preparation of the feedstock.

The conventional method for computing C/N ratio for different feedstocks composed of various portions of the organic fraction of MSW is to compute total dry weights. A second method is based on the total dry weight of the biodegradable organic carbon and total dry weight of the available nitrogen. The first method of determining the C/N ratio may not be appropriate for the organic fraction of MSW because not all of the organic carbon is biodegradable and, therefore, available for biological decomposition.

Based on pilot plant testing, it appears that almost all of the nitrogen in the organic material is available for microbial metabolism. Therefore, the C/N ratio should be based on the total dry weight of the nitrogen and the total dry weight of biodegradable carbon in the organic mass, as expressed in Equation 2 (Kayhanian and Tchobanoglous, 1992).

Equation 2

$$C/N = BCM/TNM$$

Where:
C = Carbon
N = Nitrogen
BCM = biodegradable carbon mass, % of total organic mass (dry basis)
TNM = total nitrogen mass, % of total organic mass (dry basis)

While it is more accurate to analyze samples for ultimate analysis periodically, it is possible to estimate the value of C/N ratio of a feedstock using typical values for the various waste fractions comprising the feed mix. Carbon and nitrogen concentrations for the components of a typical wastestream's biodegradeable organic fraction, which are also representative of the Folsom waste, are reported in Table 32.

The problems associated with high C/N ratios can be alleviated by removing a portion of the carbonaceous material, or by adding organic material rich in nitrogen. Because paper is the principal carbon source as well as the largest single component of the waste, the complete removal of paper will leave the remaining waste with a very low C/N ratio, which will cause ammonia toxicity problems.

At the UC Davis pilot plant it has been demonstrated that it is possible to operate the high-solids anaerobic digester at extreme ranges of high and low C/N ratios for several days. But long-term operation of the digester at a high or low C/N ratio will lead ultimately to digester failure. The high solids digester was operated at a C/N ratio of about 25-30 (based on biodegradable carbon) with no adverse effect on the digester performance. This range of C/N ratio will be used to prepare the daily feedstock for the CRRF digester.

Table 32.

CARBON/NITROGEN CONTENT OF TYPICAL MSW (1)		
COMPONENT	CARBON	NITROGEN
Foodwastes	50	3.5
Newsprint	46	0.1
Office paper	43	0.2
Mixed paper (2)	45	0.2
Yard wastes	43	2.5

(1) Average value, percentage on dry basis.
(2) 25 percent newsprint, 75 percent office paper.

Procedures for daily feedstock preparation

The following procedure is recommended for preparation of a feedstock with a C/N ratio in the range of 25-30:

1. Assume that one pound of food waste and one pound of yard waste are available for each pound of paper, as a wet measurement.

2. Determine the percentage of dry mass of the waste (see Total Solids [TS] testing below). For these calculations, each component must be tested and the results added in proportion.

3. Determine VS percentage of dry mass (see Volatile Solids [VS] testing below).

4. Determine the BVS percentage of the volatile mass (see Biodegradable Organic Fraction of MSW as a Feedstock above).

5. Calculate dry mass:

Equation 3.

Dry mass = Wet mass x TS

6. Calculate the volatile mass:

Equation 4.

Volatile mass = Dry mass x VS

7. Calculate biodegradable mass:

Equation 5.

Biodegradable mass = Volatile mass x BVS

8. Record concentration of carbon (C), using analytical test results or values reported in Table 33.

9. Record concentration of nitrogen (N), using analytical test results or values reported in Table 33.

10. Calculate the biodegradable carbon (BC) mass:

Equation 6.

BC mass = Biodegradable mass x C%

11. Calculate the TN mass:

Equation 7.

TN mass = Dry mass x N%

12. Calculate C/N ratio:

Equation 8.

C/N ratio = BC mass / TN mass

13. If C/N ratio is less than 25, add paper and repeat steps 2 through 12 to determine the new C/N ratio. If the C/N ratio is greater than 30, remove paper and repeat steps 2 through 12 to determine the new C/N ratio.

Analytical techniques and methodology for monitoring digesters

In the beginning of the operation, several parameters must be monitored on a daily basis to ensure normal operation of the high-solids anaerobic digestion process. The analytical techniques and equipment needed to measure these parameters are detailed in the following sections. The parameters include the following:

- pH
- Alkalinity
- Ammonia nitrogen
- Total Kjeldahl nitrogen (TKN)
- Volatile fatty acids (VFA)
- Biogas composition
- Biogas volume
- Reactor temperature
- Total solids (TS)
- Volatile solids (VS)

pH

The pH of the digesting material can be measured with an Orion SA 720 multi-use meter with a pH probe. The meter is calibrated with two buffer solutions (pH 4 and pH 7) and then the probe is placed in a representative digester sample. A light comes on when the measurement is complete. At that time, simply record the pH value displayed on the screen. A pH value in the range of 6.8 to 7.5 is normal.

Alkalinity

The total alkalinity is a rough measure of the capacity of a liquid to neutralize acids. Because fatty acids are produced in large amounts during the digestion process, it is often necessary to know the buffering capacity of the active biomass. This capacity results from the presence of bicarbonate (HCO3-), carbonate (CO3-2), or hydroxide (OH-), and compounds of calcium (Ca), magnesium (Mg), sodium (Na), or potassium (K).

The total alkalinity is measured by titrating a known volume (2-10 grams) of sample with sulfuric or hydrochloric acid and recording the volume of titrant necessary to bring the sample to a pH of 4.3 and the volume necessary to take it from pH 4.3 to pH 4.0. A step by step procedure for this analysis follows. The equipment needed to perform this procedure are: a scale, distilled or deionized water, a titration assembly, a beaker, a pH meter with probe stand, pH calibration buffer, and a magnetic stirrer.

1. Place a sample of the digester solids into the beaker on a zeroed balance and record the weight. Add enough distilled or deionized water to make an easily stirred liquid.

2. Calibrate the pH meter (see pH above or the meter's instruction sheet).

3. Set up the titration assembly and record the normality (number of molar equivalents per liter) of the titrant (sulfuric or hydrochloric acid). When a very low alkalinity is expected, use a 0.02 N solution, otherwise use a 0.1 N solution.

4. Mix the sample with the magnetic stirrer and set the pH probe in the stand. Adjust the stand so that the probe is immersed in the sample but in no danger of being hit by the magnetic stir bar. It may be necessary to move the probe often to prevent buildup of solids over its reaction spot (see probe instructions).

5. Slowly drip titrant into the sample, watching the drop in pH carefully and recording the volume of titrant used. Pause frequently to allow the pH of the mixture to stabilize. Titrate to pH 4.3. Record this volume. Pause. Titrate to 4.0. Pause and record volume.

6. Calculate the total alkalinity and the bicarbonate alkalinity as milligrams of CaCO3 equivalents per liter. Use the following equations:

<u>Equation 9.</u>

Total Alkalinity = (V x N x 50,000) / S

Where:
V = titrant volume to pH 4.3, mL; V' = titrant volume from pH 4.3 to pH 4.0, mL; N = titrant normality, meq/mL; S = sample mass, g

Equation 10.

Bicarbonate Alkalinity = ((V - (V'/0.85)) x N x 50,000) / S

Note: The 50,000 term is the equivalent weight of $CaCO_3$ in mg/L. The 0.85 factor is based on the assumption that VFA's are only 85 percent ionized at pH 4.0.

Ammonia nitrogen

Nitrogen, present in all proteins, enters the anaerobic digester mostly as food and yard waste. In the digestion process, organic nitrogen is converted to ammonia (NH_3). If the concentration of ammonia in the digester mass becomes greater than 1,500 mg/L, methane production is reduced. If the concentration exceeds 2,000 mg/L, the methane producing bacteria will not function and the digester may fail. Also, as nitrogen is a necessary food to many of the bacteria in the digester, too low an ammonia concentration will also cause a drop in methane production. It is necessary, therefore, to keep the ammonia concentration between 650 and 1,000 mg/L.

At UCD, the ammonia concentration is determined using a Buchi 323 Distillation Unit from Brinkmann. A distillation flask is placed in a holder (a plastic beaker works well) on a scale and the scale is tared. A sample of approximately two grams is weighed into the flask. The exact weight of the sample is recorded on the worksheet.

To shift any ammonium in the sample to ammonia, 20 mL of borate buffer solution is added (see reagent list to follow). The flask is then attached to the distillation unit and an Ehrlinmyer flask containing 50 mL of boric acid indicator solution (see reagent list) is placed on the collection shelf. The cooling water faucet is turned on and the distillation unit is started.

Reagent List

Methyl Red Solution:

Add 200 mg methyl red indicator powder to 100 ml 95% ethanol or isopropanol. Mix until dissolved.

Methylene Blue Solution:

Add 100 mg of methylene blue indicator powder to 50 ml ethanol or isopropanol. Mix until dissolved.

Mixed Indicator Solution:

Mix one batch of Methyl Red Solution and one batch of Methylene Blue Solution. Store in refrigerator.

Boric Acid Indicator Solution

Dissolve 20g of boric acid (H_3BO_3) in about 800 ml of distilled or deionized water. Add 10 ml Mixed Indicator Solution. Mix until dissolved. Dilute to 1 liter using volumetric flask. Store in dark cupboard. Replace after one month.

Borate Buffer Solution

Add 88 ml 0.1 N NaOH solution to 500 ml of approximately 0.025M sodium tetroborate ($Na2B4O7$) solution (9.5g sodium tetraborate powder per liter of solution). Dilute to one liter.

The unit should be programmed as follows, according to machine instructions: water, 75 mL; NaOH, 0 mL; delay, three seconds; run, six minutes. As the ammonia in the sample is trapped in the boric acid indicator solution, the solution will turn from purple to green.

After the machine has stopped, titrate the boric acid indicator solution back to purple, titrating until the solution will get no purpler. Titrate with approximately 0.15 N sulfuric acid, recording both the volume of titrant used and the exact normality (N) of the titrant. Calculate the ammonia concentration with the following equations:

Equation 11.

Ammonia (mg/L) = mL titrant x 14 x Norm of titrant x 1000/g sample

Equation 12.

Ammonia (g/L-moist) = mL titrant x 14 x Norm. / (g sample x TS/100)

In Equations 14 and 15, the number 14 is the molecular weight of nitrogen and 1,000 is the number of milliliters per liter. After testing is complete, steam out the distillation unit by running a blank sample of about 150 mL of distilled water.

Total Kjeldahl nitrogen

The anaerobic digestion process needs organic nitrogen to continue. If all of the nitrogen in the digester has been converted to ammonia, some kinds of bacteria will begin to starve. The standard method for testing organic nitrogen levels is the Total Kjeldahl Nitrogen or TKN test. The TKN test is done in two steps. In the first step, a sample is boiled in acid and salts to convert the organic nitrogen in it into ammonia. Then a method such as the one described above is used to determine the ammonia concentration.

The TKN is the sum of both the organic nitrogen and the nitrogen present in the sample as ammonia. The equations used for ammonia are used to calculate the TKN concentration. To determine the organic nitrogen value, a separate ammonia test is conducted on the sample and the result is subtracted from the TKN value.

The quickest way to accomplish the digestion phase of the test is with a Buchi 420 Rapid Digestion Unit from Brinkmann. Goggles, gloves and a lab coat or apron must be worn, as the reagents are caustic and hot. It is also important to know and follow carefully the operating instructions of the apparatus being used. Flasks can melt, dumping hot acid through the unit and onto the counter, if the improper sample sizes and machine settings were used. The instructions that come with each apparatus include reagent selection and preparation. Chemicals which may be included in the reagents include sulfuric acid, hydrogen peroxide, potassium sulfate, and copper sulfate.

After digestion, allow the flasks to cool and then perform the ammonia test. Machine settings on the distillation unit are different when running TKN samples, because the acid in the digestion solution must be neutralized with sodium hydroxide (NaOH). Determine the amount of base solution necessary to bring samples to pH 7 and set the unit to deliver that amount.

Volatile fatty acids (VFA) analysis

Samples must be pretreated before analysis. Centrifuge enough sludge to obtain 10 to 15 mL of clear supernatant liquid. Separate this liquid and add a few drops of thymol blue indicator solution. Then add enough drops of concentrated sulfuric acid to change the indicator solution to red (pH will be 1.0-1.2). To prepare thymol blue indicator solution: dissolve 80 mg thymol blue in 100 mL absolute methanol. Store in the refrigerator.

Volatile fatty acids may be determined by a liquid chromatograph equipped with a flame ionization detector. A Gow-Mac series 740-P liquid chromatograph equipped with a six-foot Teflon column packed with 10 percent Sp-1200 per 1 percent H_3PO_4 on 80/100 Chromosorb WAW is commonly used for the analysis of VFAs. Analysis should be performed under the following conditions: column temperature 125°C, injection/detector temperature 175°C, and N_2 carrier gas flow 30 mL/min. A Spectra-Physics SP 4290 computing integrator can be used to integrate the chromatograph output.

Biogas Composition

Biogas composition can be measured using a gas chromatograph (GC). The GC used at UC Davis is a Microsensor Technology 500 Series, but any other type will work as well. To measure the biogas composition, the GC must be calibrated with gas of a known composition. For biogas, a mixture of 50 percent carbon dioxide and 50 percent methane is used. This gas can be purchased to order.

The GC should be connected to the biogas line coming from the digester to allow gas analysis to be performed at short intervals if necessary, as may be the case if the digester begins to fail. During normal operation a sample will be taken daily for analysis. A methane concentration of 50 percent or more indicates normal operation.

Biogas volume

Biogas volume can be determined by a volumetric flow measurement device (i.e., Omega gas flow meter). The gas volume measured is normally under pressure and saturated with moisture. To report this gas volume as a dry volume, an average daily ambient temperature must be recorded. The following equation can then be used to convert the biogas volume as measured to a standard (STP), dry volume (Tchobanoglous et al, 1992).

Equation 13.

$$V = V_T [273/(273 + T)][(P - P_v)/P]$$

Where:
T = average ambient temperature
V_T = volume of biogas measured at temperature T
V = volume of biogas at STP and dry basis.
P = atmospheric pressure
P_v = vapor pressure

Vapor pressures for selected temperatures are presented in Table 33.

Table 33.

VAPOR PRESSURE AT VARIOUS TEMPERATURES	
TEMPERATURE (F)	VAPOR PRESSURE (1)
32	0.09
40	0.12
50	0.18
60	0.26
70	0.36
80	0.51
90	0.70
100	0.95
110	1.27
120	1.69
130	2.22
140	2.89
150	3.72

(1) lb/sq. inch

Reactor temperature

The temperature of the reactor contents can be measured using temperature gauges placed at several points within the reactor. The temperature of the reactor contents can also be measured with an Orion SA 720 multi-use meter with a temperature probe. For an accurate measurement this method of temperature measurement must be performed with a fresh sample of digester solids or by inserting the probe inside the reactor.

Total solids (TS)

Only a fraction of the waste fed to the digester will be converted into biogas. To balance the feed properly it is necessary to know what percentage of the various waste types will be digested. To calculate the proper proportions it is necessary to determine the percentage of total solids (TS) of the waste types. Because the percentage distribution of the waste components can change, sometimes daily, the test must be performed often. Daily testing is best.

The total solids value is also used in calculating ammonia and organic nitrogen concentration results. Total solids can be determined by oven drying a sample, as follows:

1. Record the weight of two or three ceramic drying casseroles. These are tare weights.

2. Add 50-100g of wet sample to each. Record these weights. These are called wet weights.

3. Dry samples in an oven with natural air circulation and the thermostat set to 105 °C. Allow the sample remain in the oven for a 24 hour period to ensure total moisture removal and a constant final weight.

4. Weigh the samples, and record the dry weights. The amount of moisture removed from the sample by drying is obtained by subtracting the dry weight (dry sample + tare) from the wet weight (wet sample + tare).

5. Calculate total solids (TS):

Equation 14.

Total solids, TS = 1- [(wet weight - dry weight) / (wet weight - tare weight)] x 100%

Volatile solids (VS)

As explained above, only a fraction of the waste fed to a digester will be converted into biogas. It is necessary to know what percentage of the various waste types will be digested. To calculate these percentages, it is also necessary to determine the percentage of volatile solids (VS). The dried samples produced by the TS measurements can be used for VS measurements.

Place these samples in a cold muffle furnace and gradually heat to 550°C (rapid heating may cause an explosion of the sample from the container). Hold the sample at 550°C for two hours. Take the sample out of the furnace, put it in a dehydrator and let it cool completely, then weigh it. The weight obtained is the ash weight. To test that two hours is enough time for your equipment and sample, cool and weigh the sample, then reheat it to 550°C for another half-hour. Cool and weigh. If the difference in the weights is 2 percent or less, the firing time is sufficient. It should not be necessary to test this more than once a month, under normal circumstances.

Calculate the VS:

Equation 15.

Volatile solids,VS=(dry weight-ash weight)/(dry weight-tare weight)x100%

Unbalanced digestion and possible actions to prevent digester failure

Although the high-solids anaerobic digestion process is generally robust, care must be taken to ensure balanced operation. To aid the prevention of unbalanced digester operation and to prevent digester failure, this section describes the proper methods of monitoring the high-solids anaerobic digestion process and outlines possible operational problems with suggested remedial actions to be taken when these problems arise.

Monitoring the digestion process

A balanced digester is one in which anaerobic digestion proceeds with a minimum of control. Balanced operation means that the system's environmental parameters remain naturally within their optimum range, with only occasional fluctuations. When an imbalance does occur, the two main problems are:

1. Identifying the beginning of an unbalanced condition and;

2. Identifying the cause of the imbalance.

Unfortunately, there is no single parameter that will always indicate the commencement of an unhealthy anaerobic process. The parameters shown in Table 34 must all be monitored daily. None of these parameters can be used individually as a positive indicator of the development of digester imbalance.

Table 34.

INDICATORS OF UNBALANCED DIGESTION PROCESS	
PARAMETERS	**WARNING CONDITION**
VFA concentration	Increases
Percentage of CO2 in biogas	Increases
Reactor pH	Decreases
Total gas production	Decreases
Percentage of CH4 in biogas	Decreases
Waste stabilization	Decreases
Ammonia concentration	Increases

The most immediate indication of impending operational problems is a significant decrease in the rate of gas production. If the growth of the microorganisms are being inhibited by one or more factors, it will be reflected in the total gas production. However, a decrease in the gas production rate may also be caused by a decrease in either the digester temperature or the rate at which the feed material is being added to the digester.

The most significant single indicator of a digester problem is a gradual decrease in pH. In an operating system a decrease in pH is associated with an increase in organic acid concentration. Measurement of organic acid increase is a good control parameter; however, proper laboratory facilities, equipment, and trained personnel are required to monitor organic acid. On the other hand, gas production rate and pH are simple, quick measurements that anyone can perform.

Operational problems and suggested actions

In general there are five major problems associated with the high-solids anaerobic digestion process. A possible cure for these problems are summarized below. These problems include:

1. Increase in total solids concentration beyond 32 percent,
2. Organic overloading,
3. Toxic overloading,
4. Free ammonia toxicity, and
5. Nutrient deficiency.

The following lists present suggested actions for resolving the common problems associated with the high-solids anaerobic digestion process.

Total solids build-up
- Add water

Organic overloading
- Do not feed.
- Add strong base to neutralize acids.
- Resume feeding at lower organic loading rate when pH reaches at least 6.8.

Toxic overloading
- Identify and remove the toxic element from the feedstock.
- If the population of methanogens are reduced (CH4 concentration decreased) add proper methanogen seed
- If pH decreases below 6.8, add strong base to neutralize acids.
- Resume feeding at lower organic loading rate when pH reaches at least 6.8.

Free ammonia toxicity
- Start feeding with an organic waste of higher C/N ratio.
- Dilute the active reactor mass with fresh water.

Nutrient deficiency
- Add chemical nutrient into the reactor.
- Add organic materials rich in the needed nutrients.

References

1. Chandler, J. A. , W. J. Jewell, J. M. Gossett, P. J. Vansoset, and J. B. Robertson (1980), "Predicting Methane Fermentation Biodegradability," 10th Biotechnology and Bioengineering Symposium, pp. 93-107.

2. Holland, K. T., J. S. Knapp, and J. G. Shoesmith (1987), Anaerobic Bacteria, Chapman and Hall, New York.

3. Jewell, W.J. (1979) Future Trends in Digester Design, in D. A. Stafford, B. I. Wheatly and D. E. Hughes (ed.), Proceedings of the First International Symposium on Anaerobic Digestion, Cardiff, Wales. Applied Science Publishers Ltd, London, pp. 17-21.

4. Kayhanian, M. and G. Tchobanoglous, (1992) "Computation of C/N Ratios for Various Organic Fractions", Biocycle, vol. 33, no. 5

5. Kayhanian, M. et al (1991) The Recovery of Energy and Production of Compost from the Biodegradable Organic Fraction of MSW using the High-solids Anaerobic Digestion/Aerobic Biodrying Process. A report to Prison Industry Authority.

6. Rivard, C. J., T.B. Vinzant, W.S. Adney, K. Grohmann (1987) "Nutrient Requirements for Aerobic and Anaerobic Digestion of Processed Municipal Solid Waste," J. Environ. Health, vol. 52, pp. 96-99.

7. Smith, K. T., California Resources, Consultants (1991) City of Folsom Preliminary Waste Characterization Study, Sacramento, CA.

8. Speece, R. E. and P. L. McCarty (1964), "Nutrient Requirements and Biological Solids Accumulation in Anaerobic Digestion," In : Advance in Water Pollution Research, Vol. 2, ed. W. W. Eckenfelder, Pergamon Press Ltd, Oxford, England, pp. 305-322.

9. Speece, R. E. and Parkin, G. F. and Gallagher, D. (1983) "Nickel Stimulation of Anaerobic Digestion" Water Research, vol. 17, pp. 677-683.

10. Speece, R. E. and Parkin, G. F. (1985) "Nutrient Requirements for Anaerobic Digestion" in: Biotechnological Advances in Processing Municipal Waste for Fuels and Chemicals, ed: A. A. Antonopoulos, ANL/CNSV-TM-167, Argonne National Laboratory, Argonne, Illinois, pp. 195-221.

11. Standard Methods for Water and Wastewater, 17 th ed.(1989), American Public Health Association.

12. Stone and Webster Engineering Corp. et al (1990) Waste Recycle Energy Plant Feasibility Study, Volumes I and II, Report prepared for the Prison Industry Authority, San Francisco, CA.

13. Tchobanoglous, G., H. Theisen, and H. Vigil (1992), Integrated Waste Management: Engineering Principles and Management Issues. McGraw-Hill Book Company, New York.

APPENDICES

SAMPLE WORKSHEETS

Prison Industry Authority
Folsom Waste-To-Energy Recovery Facility
Daily Work Sheet for Anaerobic Digesters

Date	Time	Reactor temp. (°C)	Biogas temp. (°C)	Biogas volume (ft3)	Biogas CO2 (%)	Biogas CH4 (%)	Norm. CH4 (%)	Reactor pH	Inflow Paper mass (lb)	Inflow Yard mass (lb)	Inflow Food.W mass (lb)	Inflow Other mass (lb)	Inflow water mass (lb)	Total inflow mass (lb)	Total effluent mass (lb)	COMMENTS

Inflow Other Mass: Dairy Manure (*) Sludge (+) ; Nutrient (-)

Prison Industry Authority
Folsom Material Recovery Facility
Daily Work Sheet for Total and Volatile Solids Analysis

Date	Sample ID	Tare (g)	Wet+Tare (g)	Dry+Tare (g)	Ash+Tare (g)	TS (%)	VS (% TS)	Average TS (%)	Average VS (% TS)

Prison Industry Authority
Folsom Waste-To-Energy Recovery Facility
Daily Work Sheet for Ammonia and TKN Analysis

Date	Sample ID	Flask #	Sample size (gr wet)	TS (%)	Titrant norm.	NH3-N				TKN		
						Titrant (ml)	1 (mg/l)	2 (g/kg-dry)	3 (g/lm)	Titrant (ml)	1 (mg/l)	2 (g/kg-dry)

Formula 1: (ml Titrant*14*Norm.*1000)/(gr wet) = mg/l
Formula 2: (ml Titrant*14*Norm.)/((gr wet)*TS/100) = mg/g-dry
Formula 3: (ml Titrant*14*Norm.)/((gr wet)*(1-TS/100)) = g/lm

Prison Industry Authority
Folsom Waste-To-Energy Recovery Facility
Daily Work Sheet for VFA Analysis

Date	Sample ID	Sample weight (g)	Sample diluted (g)	Dilution factor (g S/g D)	Diluted VFA, mg/l as Acetic Acids FID results						Sample VFA, mg/l as Acetic Acids normal basis for reporting						total
					C2	C3	iC4	nC4	iC5	nC5	C2	C3	iC4	nC4	iC5	nC5	

Prison Industry Authority												
Folsom Waste-To-Energy Recovery Facility												
Worksheet for Feedstock Preparation												
Organic matter	Wet mass	TS % wet mass	VS %TS	BVS %VS	Dry mass	VS mass	BVS mass	C Conc.	N Conc.	B.C. mass	Total N mass	C/N ratio
	1	2	3	4	5=1x2	6=3x5	7=4x6	8	9	10=7x8	11=5x9	12=10/11
Mixed paper	2.1	94	95	70	1.97	1.88	1.31	45.00	0.19	0.59	0.004	157.50
Yard waste	1	52	82	65	0.52	0.43	0.28	43.00	2.50	0.12	0.013	9.17
Food waste	1	30	90	80	0.30	0.27	0.22	50.00	3.50	0.11	0.011	10.29
Feedstock C/N Ratio =			**30**									