The Strategic Envirotechnology Partnership

Green Book Technology Summary

Fertilizer Manufacturing Through Enhanced Autothermal Thermophilic Aerobic Digestion (ATAD)

Bio-Dynamics LLC
48 Junction Square Drive
West Concord, MA
978 371-0700

Prepared by:
Thomas Flanagan, Ph.D., MBA
UMass Boston, EBTC
100 Morrissey Boulevard, Boston MA 02125-3393
617 287-7726

This standardized reporting format is consistent with the Department of Energy's Green Book Technology Summary reports and is also adapted from the Environmental Protection Agency – Region 1's Pollution Prevention Application Analysis Template, developed by Stone & Webster Environmental Technology & Services.

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DISCLAIMER

This document is designed to assist the user in analyzing the application of technologies. While it provides a template for the general types of questions that you should ask when evaluating a technology, it may not include all of the questions that are relevant to your business, or which your business is legally required to ask.

This document is intended to assist envirotechnology users, developers, and investors to make informed decisions about the commercial potential of specific products or prospective products under development. This document is not intended to communicate the full market scope or competitive position of any of the underlying technologies embodied by the product, but rather to illustrate the comparative effectiveness, or potential effectiveness, of that technology in the form of one or more specific products.

NOTE: This design review document is not complete unless accompanied with an appendix (page 42) containing a signed letter from the technology proponents asserting that, to the best of their knowledge, the design issues reflected in this document are complete and accurate. In the course of preparing this document, no direct audit of system performance has been conducted by STEP.

INTRODUCTION

The Environmental Problem: Non-point source watershed pollution has become a central focus of environmental control activity. Within this context, the public perception of parklands, greenways, and farmland homesteads is shifting from a traditional view of these enterprises as “close to nature” to a new view of these enterprises as industrial activities that are likely to have enduring adverse impact upon water quality. The factors which underlie these changing views include concerns about current uses of fertilizers, insecticides, herbicides, and fungicides, and concerns about current practices for managing wastes, waste water, and rain water runoff.

A significant indicator of the changing view toward agricultural practice is represented by a reclassification of dairy farms (of specified scale) as commercial operations subject to rules for industrial environmental compliance. The mystique of the wholesomeness of the American farm is giving way to a get-tough-on-agriculture trend. However, a parallel trend exists to rally support for innovations that will foster sustainable agricultural practices. American agriculture, particularly in urbanized regions of the nation, is under considerable economic pressure, and has been in an accelerated decline for the past several decades. In this context, innovations which promote faster, more efficient, and less costly crop production while concurrently reducing nutrient runoff and soil erosion are poised to make significant contributions to emerging practices of sustainable farming.

There is little doubt that there exists considerable opportunity to generate fertilizer for large scale use from organic wastes through composting and other innovative treatment methods, such as the one reviewed in this report . A significant level of the municipal waste stream consists of organic matter appropriate for composting, and these same waste streams are commanding increasing tipping fees both because land fill space is in continuing decline and because organic wastes pose specific waste handling challenges. “Organic materials make up the bulk of America’s discarded municipal solid waste. In 1996, organic materials accounted for 141 million tons (67 percent) of the waste stream. Some organic materials, such as newspaper, office paper, and corrugated, have a high recovery rate. Other organic materials (e.g., yard trimmings, food scraps, and certain grades of paper), however, still tend to be landfilled and represent an area with high growth potential for recovery (75 million tons). Depending on the type of waste and method of composting selected, average national savings over conventional disposal vary from $9 to $37 per ton for 62 million tons of the MSW stream” (EPA 530-R-99-016, July 1999). In land fill settings, organic waste generates odors, attracts vermin, raises health concerns, and impedes manual sorting of recyclable waste. For all of these reasons, municipalities favor options for specifically removing organic materials from the municipal waste stream. Composting, in any of its many contemporary forms, is the preferred option.

There is also little doubt that, when manufactured to market specifications, compost is a valuable soil amendment. While markets for high quality compost are still emerging, the EPA has investigated the utility of compost as an agricultural product and has formed the conclusion that fertilizer and soil amendment products formed from organic wastes can add value to:

1. Bioremediation and Pollution Prevention (through reduced insecticide and fungicide use)
2. Disease Control for Plants and Animals;
3. Erosion Control and Landscaping;
4. Composting of Contaminated Soils;
5. Reforestation, Wetlands Restoration; and
6. Habitat Revitalization

In spite of continued efforts to expand agricultural, municipal and residential acceptance of soil amendments manufactured from municipally recycled feedstock, concerns over the quality and consistency of these products have delayed broad spread adoption. End users of municipally manufactured fertilizer are significantly concerned about both inter-batch consistency (including seasonal consistency) and overall quality (including elimination of pathogens, toxic metals, odors, and debris – such as glass shards, and metal and plastic fragments).

<u>The Requirements for Technical Solutions</u>: Composting, or more generically, bioconversion of an organic feedstock waste stream into a microbially-enriched soil amendment, has been evolving continually for hundreds of years. In general, all forms of composting are based upon a microbial bioconversion of cellulose-rich feedstock into an amendment enriched to varying degrees with microbial products. On one end of this spectrum, the feedstock is only modestly altered while on the other end of the spectrum, the feedstock is converted predominantly into a microbial biomass. A substantially altered microbial product acquires properties that are distinct from the feedstock and which may have specific appeal to specific end users. Product evolution represents one dimension of technical solution for composting practice.

Historically, agricultural feedstock could spontaneously "compost" as mounds of organic matter upon agricultural fields. Urban feedstock sources lack sufficient composting space and impose additional demands for odor control. It is widely recognized that odor related to composting is primarily associated with anaerobic bioconversion of largely nitrogen-rich feedstocks. Most modern innovation in composting practice involves "aerating" compost systems to minimize malodorous conditions. Recent innovation has focused along two divergent management strategies: (1) optimize gas capture and re-use from systems using odor-generating, anaerobic processes or (2) minimize odor and gas generation through aerobic processes. For each individual application, the technical solution must consider the composition of the feedstock, the performance requirements of the product, and constraints placed upon the production process itself. Process evolution represents the second dimension of technical solution for composting practice.

This document seeks to characterize, in a concise manner, the main features of a manufacturing facility utilizing autothermal thermophilic aerobic digestion as a means of generating a microbial biomass product for use as fertilizer. This report will consider both the product and the manufacturing process in terms of its benefits, the costs associated with its implementation, regulatory aspects, and lessons learned from the development and application of this approach. The success of this document will be measured in its ability to promote an understanding of the process, and to accelerate the appropriate use of the enabling technology.

TECHNOLOGY SUMMARY

Overall Process Schematic

The technology proponents offer a manufacturing system plan and a management strategy for using an in-vessel, slurry system to convert waste food scraps into a stable, microbial biomass product. The product is intended for uses as a fertilizer, either as a fertilizer directly or as organic filler for a chemical fertilizer product. The manufacturing system consists of:

a supply chain for feedstock;
a central processing facility; and
a product packaging capacity.

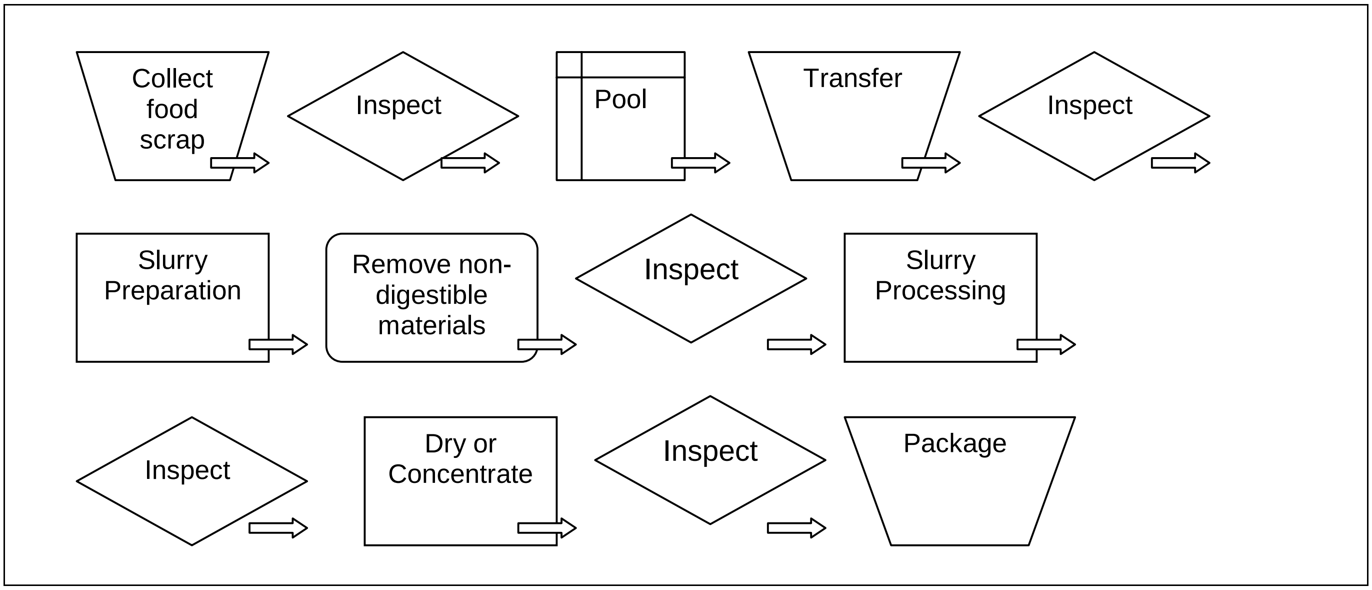
The supply chain exists in the form of a contracted network of pre-sorted, processed food scrap producers, transfer and slurry generation sites, and bulk and slurry feedstock haulers. The central processing facility is based upon autothermal (or autogenous) thermophilic aerobic digestions (ATAD), a technology with a long history of practice in the municipal wastewater sludge management sector (see EPA/625/10-90/007 September 1990). The technology is based upon the use of a class of naturally abundant microbes that thrive at high temperature, and establishing for these microbes a food source concentration and oxygen supply that will allow them to self-generate their preferred high temperature growth conditions. At the completion of microbial digestion, product-packaging operations consist of drying, pelletizing and bagging, or, alternatively, thickening and bottling dry and liquid product, respectively. The overall fertilizer manufacturing system is modeled after a currently operating, 55 ton per day municipal facility, which recently upgraded to 100 ton per day, located in Vancouver, British Columbia. This precedent facility began operations in 1994, and with time allocated to expanding operations, has over 4 years of full capacity operating history.

The process technology examined in this report includes improvements upon the precedent facility in the form of a change in operating scale to allow processing of 200 wet tons slurry feedstock per day, and the use of an additional environmentally-benign technology to provide an added dimension of odor control assurance. The precedent facility in Vancouver has experimentally processed a variety of feed stock types, including residuals. The proponents of the use of the technology examined in this report assert that residuals treatment will not be operating feature of the Uxbridge fertilizer manufacturing facility.

TECHNOLOGY SUMMARY

Process Overview

Process Schematic



The central manufacturing facility examined in this study has energy / utility demands principally in the form of transportation to the processing site, and, once within the site, both in the form of supplemental heating for the start-up digestor, for driving the Shearator™ aeration and mixing systems, and for drying end product as well as regulatory requirements.

Constraints on System Design

Glass shards and fragmented metal and plastic debris that are commingled with municipal feedstock supplies need to be removed prior to and during the manufacturing process. Stringent feedstock pre-sorting criteria primarily control admission of restricted materials. Extensive screening and filtering steps remove non-bioconvertable components during the manufacturing process. These screening and filtering requirements are asserted to be best met by using a liquid slurry bioconversion process. This constraint on the system design is imposed by market demands for the finished product.

Conversion of feedstock into biomass product needs to occur at high efficiency, rapid cycle time, and practical cost. High efficiency of product yield from feedstock and efficient use of capital assets through high feedstock throughput present economic demands upon the system design. Capital costs for aerobic and anaerobic organic slurry bioconversion processes are comparable. Thus, liquid aerobic bioconversion is preferred over liquid anaerobic bioconversion for the following reasons:

1. anaerobic digestion converts up to 75% of feedstock fertilizer value into odorous and flammable gases (Tchobanoglous & Burton, 1998);
2. anaerobic digestion does not guarantee pathogen removal during processing; and
3. typical anaerobic detention time of approximately 20 days (followed by an additional 30 to 90 days of "aging") compares unfavorably with aerobic processing times of 3 to 7 days.

Additionally, the process examined in this document has the capacity to blend incoming slurry with hot recycled filtrate, such that recycled fluid may reduce the amount of applied heat (i.e. steam) needed to bring the slurry to processing temperature. This thermal recycling feature is asserted to reduce processing time by 15 % annually in northern latitudes.

Stabilizing the microbial end product, including incidental odor related to the production process, is a regulatory requirement effecting the system design. The EPA has recognized that product generated from slurry organic feedstock through the action of appropriately managed autothermal thermophilic aerobic digestion is not a source of objectionable odor. Specifically, prior EPA studies have stated "*Exhaust air was generally characterized as having a humus-like odor that did not require treatment. With an increasing number of facilities located in non-rural areas, provisions for odor control have become routine*" (ibid, page 26). Facilities using such processes may or may not be equipped with special odor control systems. Where odor control systems are employed, biofilters represent a common, effective control mechanism. Where odor problems have been identified*, "most odors were short-term events that occurred when raw sludge was pumped into the reactor and when raw sludge odors were stripped out into the exhaust. One plant reported odors when the temperature in the second-stage reactor approached 70^{o}C*" (ibid., page 26). Proponents of the technology examined in this report feel that such odor was most likely caused at the end of the digestion by the release of ammonia due to a high pH. Proponents of the IBR ATAD process assert that ammonia is not released under conditions of optimal microbial processing as evidenced both by an absence of odor (see subsequent sections) and a constant nitrogen-phosphorous-potassium ratio in feedstock and end product (see subsequent sections).

Product stabilization through on-site dry packaging and liquid bottling, and full entrapment and filtration of air cycled thorough the processing facility, represent design constraints placed on the system by requirements for odor control. Odorant molecules are channeled to and degraded within a biofilter (see subsequent section), and passage ways to and from the processing floor are additionally treated with volatized essential oils when ever doorways are open. Essential oils entrap and attenuate odors (see subsequent sections).

Ease of process management is a design constraint to provide quality control of feedstock and product and quality assurance for system performance. Component quality control elements of the precedent IBRC fertilizer manufacturing facility consist of inspections and of containing all transfer operations within a single building maintained under negative pressure and from which all air streams are fed into a biofilter. Key quality control features include, but are not limited to:

1. Visual inspection of individual pails of waste scrap for co-mixed materials;
2. Chemical analysis (N-P-K) of representative incoming lots of slurry for consistency ;
3. Visual inspection of incoming non-slurry scrap from de-packaging sources;
4. Continuous olfactory monitoring of air quality within the building by staff within the building;
5. Thermal, chemical and pH monitoring throughout the process;
6. Visual, olfactory, and chemical (Nitrogen-Phosphorous-Potassium) characterization of the solid and liquid finished products.

TECHNOLOGY DESCRIPTION

Overview of Collection and Transport System

Key elements of the supply stream management strategy:

- food wastes are converted to slurry at the supermarket site using new technology.
- slurry will be stored in underground tanks (similar to septic tanks) where low pH and anaerobic conditions will limit odor production
- slurry will be pumped into vacuum trucks and hauled to the manufacturing facility where it will be off-loaded in a sealed building

The technology and the management practices of the food scrap collection and pre-processing system that Bio-Dynamics, the proponents of the technology under review in this document, will employ is beyond the scope of this technology assessment. For this reason, this aspect of the overall system design will be discussed only in limited detail in this report. The photograph shown at right illustrates an example of the type of collection truck used by National Challenge Systems Inc. (NCSI), Coquitlam, British Columbia. NCSI is the exclusive distributor for agricultural technologies of Organic Resource Technology Inc. (ORTI), Guelph, Ontario. ORTI has technologies related to on-site dry grinding and liquid slurry storage and transfer of organic residuals. NCSI has packaged ORTI technologies into an integrated system ("Organic Resource Recovery System") consisting of milling solids into a slurry, holding slurry, vacuum transfer of slurry, and transfer to processing facilities. Bio-Dynamics' partner, IBR, has adopted the ORTI approach as the collection methodology for their Vancouver facility (www.ibrcorp.com).

Details of the Bio-Dynamics collection plans have been reviewed by STEP, and those plans appear consistent with the general operating principles of NCSI and ORTI as discussed in corporate materials from those firms (see also www.nationalchallenge.com). Bio-Dynamics indicates that collection and transport from food scrap generating facilities will be overseen by Suburban Companies (www.suburbancleaning.com), a Massachusetts-based firm whose principals have experience in facility support and in waste hauling within the Commonwealth of Massachusetts. Incoming lots of feedstock will be collected into a receiving vessel for quality testing. Rejected lots, if and when encountered, will be hauled under manifest to disposal sites.

Overview of Receiving and Processing System

STEP has conducted a design review for the proposed Uxbridge facility. Performance statements are based upon prior EPA analysis of ATAD technology and STEP's current analysis of third party examinations of the Vancouver ATAD manufacturing facility. The processing system employed within the central manufacturing facility under study in this report conforms with design standards for the use of autothermal thermophilic aerobic digestion (ATAD) for municipal sludge processing facilities, with the significant distinction in the feedstock used for the manufacturing facility. ATAD technology has been extensively reviewed by the EPA in a study released in September of 1990 (EPA/625/10-90/007). In this prior study, EPA researchers determined that ATAD provides a proven, cost-effective way to achieve aerobic digestion and to produce sludge that can be land applied. "The ATAD process has many benefits: a high disinfection capability, low space and tankage requirements, and a high sludge treatment rate. It is a relatively simple technology that is easy to operate (automatic monitoring or control equipment and full time staff are not required) and economical, particularly for small facilities. It provides a proven, cost-effective way to achieve aerobic digestion and to produce sludge that can be applied to land in the US without any management restrictions for pathogen control" (page 1). The document further concludes that "ATAD process can be operated to meet the most stringent U.S. regulatory requirements" (see page 31).

The principal component elements of the fertilizer manufacturing facility plan examined in this analysis consist of:

1. A set of tanks for receiving and inspecting incoming macerated slurry;
2. A secondary tipping floor, conveyor, and macerator system for sorting and pre-processing incoming non-slurry feedstock;
3. A secondary hammer mill for pre-processing incoming non-slurry feedstock recalcitrant to maceration alone;
4. A primary macerator wherein pH is elevated and debris (i.e. commingled plastic) is collected;
5. A primary gravity settling tank where grit is collected;
6. A start-up digester equipped with a Shearator™ aeration system and foam cutter, and an auxiliary heating capacity wherein microbes are introduced into the slurry stream;
7. A means of collecting off-gasses from the start-up digestor and channeling them to a biofilter;
8. A primary digester equipped with a Shearator™ aeration system, foam cutter, and grit trap;
9. A primary screen chamber, where coarse particulate materials are removed and shunted to a reject digester;
10. A parallel reject digester to degrade coarse particulate matter either into disposable waste or digestible slurry;
11. A secondary digester equipped with a Shearator™ aeration system, foam cutter, and grit trap;
12. A secondary screen;
13. A collecting tank for mixing polymer with digested slurry;
14. A press for de-watering digested slurry;
15. A filtrate tank to collect liquid filtrate from the press (approx. 60% volume);
16. A means of recycling filtrate to and through the reject digester, and/or to the primary macerator;
17. A means of collecting some volume of the filtrate as a liquid fertilizer product;
18. An indirect dryer for drying pressed, digested product;
19. A means of collecting off-gasses from the dryer and channeling them to a biofilter;
20. A mixer for blending dried product;
21. A pelletizer for molding dried product;
22. A bagger for packaging dried product;
23. A modest negative pressure on the entire building for gas control;
24. A system of infusing vented air streams with atomized droplets of water coated with essential oils to control potential fugitive odor emissions;
25. An external biofilter to receive essential oil-treated building air and digester vessel off-gasses as a primary means of odor control.

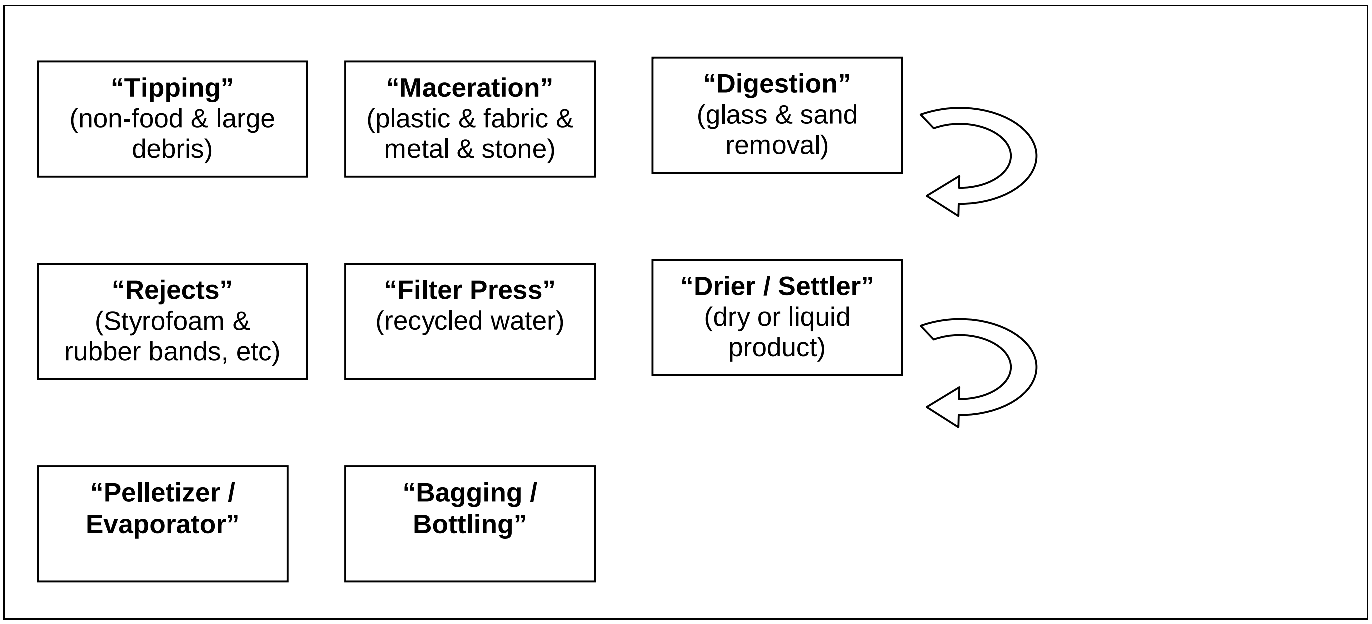
STEP has examined the design for the facility and concludes that the proposed facility will include all of the elements of benchmarked ATAD systems related to bioconversion of feedstock into product. Proprietary innovative technology related to the processing facility consists of:

TECHNOLOGY DESCRIPTION

1. An apparatus called a Sherator™ for aerating digesters with infusions of micro bubbles. This patented (US 5,660,766) submerged aeration device saturates the slurry in the digestor with oxygen and optimizes the digestion process.
2. A digester vessel design to enable a succession of filtration steps that remove non-biodegradable materials from the product stream. A patent is pending for this innovation.
3. A "reject digester" which accepts poorly digestible solids and extracts digestible material to increase product yield. This digester minimizes waste material transferred off site for landfill disposal.

Detailed Description of Receiving and Processing System

Central Facility Process Overview Showing In-Process Screening of Feedstock and Microbial Product from Non-Convertible Materials



Flow Diagram for Material and Energy Transfer

The biological process for fertilizer manufacture is an oxygen-driven conversion of carbohydrates, fats and proteins into microbial cellular products and carbon dioxide, with a coincidental net reduction of the water content of the feedstock slurry, and can be written as follows:

Feedstock + Oxygen + Microbes + Pumping + Mixing + Polymer + Drying
–> CO_2 + H_2O + Heat + Biomass + Non-biodegradable Debris

240 tonne 10% solid content food scrap + 36 liters of 50% caustic lime + 100 million cubic yards of air
+ 348 kWh of electricity + 22 cubic yards of natural gas + 48 liters of polymer
–> (NA) CO_2 + ~ 14 tonnes of vented H_2O + ~168 tonnes of waste water + 34 tonnes of liquid product +
14 tonnes of dry product +approximately 7 tonnes (3% of dry weight input) as land fill waste

Proponents of the IBR ATAD process indicated that the material balance equation as estimated above will be marginally accurate until the feed stock has been specified. The focus of operations at the Vancouver facility has been targeted at validating the use of the process upon a range of feedstock types with equivalent resulting end product. For these reasons, the ATAD process has not been optimized for resource use for specific feedstock types at this time. The equation is not balanced specifically in terms of the amount of carbon dioxide (a recognized green house gas) from the consumption of organic carbon to both power the bioconversion of feedstock into microbial product and to generate the metabolic heat required to sustain the autothermal process itself. According to an EPA assessment of the ATAD process, the process oxygen requirement (POR) for ATAD is 1.42 kg O2 per kg of VSS converted into microbial biomass (page 28, EPA 625/10-90/007). By design, aeration is optimized to favor complete conversion of feedstock to microbial biomass, and the reported high quantitative yield of the process (> 90%) is consistent with expectations for efficient bioconversion.

Recent patents on improvements in ATAD technology have asserted that elevated oxygen levels correlate with elevated temperature from metabolic heat. Because off-gassing of ammonia is significantly favored by temperatures around 70^{o}C, one might expect highly aerated ATAD systems to be subject to heat-related odors. However, proponents of the IBR ATAD process assert that across their range of operating temperatures, neither odors nor any measurable net loss of nitrogen are observed (see pg. 23). STEP has collected no data to directly corroborate these assertions (see subsequent sections for discussions of odor-free operation).

- By design, incoming feedstock will be collected into 9000 gallon receiving chambers and will be analyzed for chemical and physical composition. As needed, facility process water will be blended into the feedstock to yield a slurry with 8% to 10% solids content.
- The feedstock slurry is initially heated and aerated in 35,000 gallon digesters equipped with Shearator™ impellers. Digestion (within both primary and secondary digesters) occurs over a 41 to 72 hour period at temperatures between 60 – 85 ^{o}C. Elevated temperature is self-generated through the action of microbial metabolism. Feedstock is processed as a batch until the autothermal process peaks. This inflection point is interpreted as indicative of a depletion of the feedstock and a shift toward autodigestion of microbial products. The endpoint typically occurs within 40 to 72 hours, depending upon the composition of the feedstock (i.e. high paper content will delay the autothermal endpoint). Minimal operating conditions have been set for a 60-hour retention time at temperature above 55^{o}C.

Photographs shown above were taken from the IBR website (www.ibrcorp.com) and illustrate the working floor near the primary incubator at the Vancouver ATAD food waste manufacturing facility. STEP has not conducted a site visit of this facility and includes this image for illustrative purposes only.

- Off gases from digesters are treated with atomized aqueous dispersions of essential oils and are directed into a biofilter for microbial decomposition. All organic material transfer processes are conducted under fully contained conditions, and odor control processes are deployed. Plans reported to STEP assert that at no time will incoming feedstock be stored on site for any period greater than 3 days, and at no time will stabilized microbial end product be stored on site for more than 60 days. Dried and bagged end product, and bottled liquid product, held under ambient temperature for periods greater than three months are asserted to remain odor free.

Water contained in the incoming food waste slurry is partially recycled during the digestion process to save on heating costs. Approximately 15% of the incoming water ultimately passes through the facility biofilter in the form of air vapor from digesters and from drying ovens (and thereby contributes to the hydration requirements of the biofilter). About 14% of incoming water contributes to the liquid end product. The remaining water contained in the incoming food waste (about 25,000 gallons per day) is discharged to waste water treatment facilities, in compliance with local wastewater treatment requirements.

Atmospheric air is drawn into the system, and, within the heated digester, expands. Expanding gases exit the digesters and are passed through a biofilter as they are returned to the atmosphere. Approximately 13 million cubic yards of air pass through the system daily.

Temperature is maintained by heat generated through microbial metabolism. The digester temperature is regulated through control over the amount of oxygen that is “mixed” into the fluid through the action of submerged aerators (i.e. Shearator™ units).

Heat is subsequently used to dry a portion of the product that represents approximately 12% to 13% of the solid matter suspended in the incoming slurry. Heat for product drying is generated by a steam boiler fuelled by natural gas to generate 20 tons of dry and concentrated liquid product from 200 tons of slurry feedstock. Process conditions for resource use will need to be optimized for specific feedstock compositions.

Electricity is used to drive pumps and aeration equipment. The technology proponents assert that approximately 35 GW of energy are consumed for processing 200 tons of feedstock.

Overview of Odor Control and Product Stabilization

Regulatory provisions require the proposed manufacturing facility to remain in compliance with respect to odor control. Prior review of ATAD systems and odor control technologies indicate that the proposed manufacturing facility should be able to operate within full regulatory compliance.

> “ATAD odors are characterized mainly as humus-like, with some gaseous ammonia.... Ammonia is released by thermophilic aerobic degradation during digestion and cannot be avoided. Ammonia is not subsequently nitrified due to the suppression of nitrification at thermophilic temperatures. Depending upon the pH of the reactor, ammonia can be stripped into the exhaust. ATAD systems typically exhibit an elevated pH, particularly in the second-stage reactor, which enhances the stripping potential for ammonia. (EPA/625/10-90/007 September 1990, page 26)” Such ammonia is removed from the air as air is passed thorough biofilters.

> “The biofilter consists of a simple tank containing a filter bed of biologically active material (compost, bark, or similar material). Odors are removed by adsorption and digestion. The filter bed should have a moisture content between 40% and 60%. A water scrubber precedes the actual filter to pre-humidify the air to a moisture level of about 95%.” (ibid, page 27) In the technology examined in this report, highly aerated digesters function as water scrubbers in their ability to pre-humidify air before it enters into the biofilter.

Details of Odor Control Systems

Advantages (Disadvantages) of Options for Common Odor Management Approaches:

Chemical Wet Scrubbing	Impregnated Carbon	Bio-Filter
small footprint	high removal efficiency	no chemicals required
good removal	simple design	effective at high PPM
Efficiency handles high H_2S loads	(needs chemical regeneration)	(air must be captured)
(high O&M costs)	(landfill of spent carbon)	(larger land area needed)
(complex system)	(only treats low PPM)	(landfill of bio-material)
(high maintenance)	(air must be captured)	
(air must be captured)		

ATAD facilities may or may not require special odor control systems. Where odor control systems are employed, biofilters represent the common and effective control mechanism. Currently proposed features of the Bio-Dynamics' biofilter design have been benchmarked against best practice biofilters within the State of Massachusetts. Critical management practices for benchmarked biofilters included scheduled watering of filler material and inspecting for "dry spots" (either with surface inspection or through spot excavation to a depth of 2 feet). Practices differ with respect to the amount of active turning of filler materials in different sites.

Benchmarks for Biofilters Used for Food or Agricultural Product Manufacturing System:

Parameter	***Subject Biofilter***		
Site	***Vancouver***	***Marlborough, MA***	***Somerset, MA***
Vendor	***IBRC***	***Bedminster***	***Fay, Spofford & Thorndike, Inc.***
Waste type	Food scrap	MSW & sludge	Sewage
Equivalent Solid Waste Ton/Day	20 tons	180 tons	~ 3 Tons
Organic product rate	N/A Kg/d	<10 ppm total non-methane VoC	<2 ppm Total non-methane VoC
Use of Scrubber	equivalent	yes	yes
Canopy / Enclosure	Canopy	Enclosure	Enclosure
Total air into the filter	8,970 CFM	110,000 CFM	25,000 CFM
Filter volume	7,200 cu ft	1,350,000 cu ft	38,480 cu ft
Maximum loading rate	4.98 CFM /sq ft	4 CFM /sq ft	4.16 CFM /sq ft
Working back pressure	NA	2 " (6 mos.)	4 ½ " (2 yrs.)*
Void volume	60%	NA (compression)	NA (compression)
Reaction time	50 seconds	70 seconds	~ 90 seconds
Specific biomass load	Proprietary (manufactured matrix)	Soft wood chip and mature leaf compost (3:1)	Soft wood chip and mature leaf compost
Expected bed life	3 years	2 years	7+ years
Respiration activity	N/A	N/A	
Dispersion Stack	none	30 ft updraft fan	available, not in use
pH	Neutral	Not monitored	Neutral (leachate)
Notes		Scrubber brings NH4 from 5 ppm below threshold	Scrubber brings NH4 below 40 ppm

Note: The Somerset biofilter reports an abundance of earth worms in their filler, which is felt to contribute to accelerated consumption of filler (> 100 yards per year), but which may also account for improved air flow and reduced back-pressure. Leachate from this facility empties into a drain on site and was not a source of detectable odor on the day the site was examined. Leachate volume is felt to match the amount of water added to humidify the biofilter, but a mass balance has not been established to date.

Primary Odor Control System: Biofilter Odor Capture

The primary odor control system will be total facility containment wherein air is forced through a biofilter. Odor management through physical containment is a well-established practice, and biological air filters, or "biofilters," have well-established applications for the removal of low odors in high volume air streams from food processing plants (e.g. meat processing, food fragrance production and fermentation processes), composting operations, and even sewage treatment plants (H.A.J. Hoitink and H.M.Keener, 1993). The Food Manufacturing Coalition (FMC; www.foodsci.unl.edu/fmc/4odors.htm) asserts that "The biofilter has been shown to effectively control odors produced in food processing (Odor Control of Food Processing Operations by Air Cleaning Technologies, page 10)." STEP's comparison of biofilter designs indicates that biofilter can effectively manager even exceptionally challenging odors.

Biofilter design considerations include the size of, the composition of, and airflow path through the filter bed. Biofilter media typically consists of a physical blend of substances such as compost, peat, bark and inert matter (e.g. styrofoam balls) formulated to provide a high wetted surface area, a uniform air flow transmissibility, and resistance to compaction, clogging and physical deterioration for their geographic region of use. Local bacteria colonies grow on the surface of the filter bed, where they consume organic matter that becomes dissolved into water film within the filter. For this reason, the air stream inlet flow must have a consistently high relative humidity and have a temperature that will not harm the microbial population. IBR has evaluated a $100,000 enclosed biofilter for a 240 tonnes (270 tons) per day facility with costs distributed as follows:

Biofilter shell	$ 20,000
Medium	$ 50,000
Controls	$ 3,000
Odor system	$ 7,500
Construction Labor	$ 9,000
Support Equipment	$ 5,000
Shelter / Canopy	$ 10,000

STEP has examined a third-party report prepared by Source Test Limited under contract for IBR titled "International Bio-Recovery Corp. Bio-Filter Emission Test Report (January 19, 2000)." This study assesses IBR's ATAD gasses passing though a 30 foot by 60 foot bed surface equipped with a "green-house style" canopy over three one-hour monitoring sessions. Testing was conduced in compliance with the "GVRD Stationary Emission Testing Requirements." Results observed over the course of the three-hour study period during which a full complement of five (5) 60,000 liter digesters were operational are shown below:

Parameter	Average	Std.Dev.	CoV
temp C	17.8	0.1	0.3%
% O2	20.9	0.0	
% Moisture	1.5	0.1	3.8%
CFM	21,132	169	0.8%
Ammonia ppm*	3.25	0.28	6.5%
Phenol ppm*	0.003	0.002	76.6%
H2S ppm*	0.069	0.042	59.4%

* ppm conversions from mg/m3 using Handbook of Environmental Data on Organic Chemicals

The IBR facility was permitted for air volumes not to exceed 24,735 CFM. The low ammonia and reduced sulfur compound level is consistent with IRB's claim to operate under conditions of no detectable odors. STEP has not directly corroborated this claim either by site inspection or through a review of records of local public health offices.

Biofilters are custom designed to manage peak loads, and may additionally be designed in anticipation of potential future plant expansions. To avoid expenses in redesign, typical biofilters are engineered with some consideration for expansion (e.g. some near-by reserved space where an additional biofilter cell could be added into the system). In the unlikely condition where a biofilter might be under-engineered, quick remedies (potentially capturing about 25% more capacity) may include expanding the depth of the filter cells by adding more biologically active filler. The science of biofilter design has progressed continuously over the past several decades such that, within the Commonwealth, biofilter designers now routinely develop biofilters that meet a wide range of specific performance specifications. Key parameters of the biofilter design reported for the IBR precedent facility (e.g. maximum loading rate and reaction rate) are comparable with systems known to be effective in odor management (page 12).

Vapors that condense within the filter may, in some systems, leach from the filters. Unless condensate leaching is known not to be an issue, some provisions for controlling leachate is recommended.

The capital cost of biofilter systems is reported to be comparable to those of alternate technologies such as air scrubbers and adsorption systems. Biofilter operating costs are considered to be minimal due to the fact that they consume no chemicals or energy (except for electric fans to drive air through the filter) and require minimal instrumentation and monitoring. The major costs are filter bed media replacement (every 3-5 years) which typically represents a 10% depreciation of total capital cost per year. The IBR system proponents assert that, through a design that eliminates biodegradable material within the IBR biofilter, no detected change in the pressure was observed across their biofilter bed over the course of one year of continuous operation. For this reason, the IBR system anticipates deferring biofilter depreciation costs.

Secondary Odor Control System: Essential Oil Odor Capture

While many systems operate with only a primary odor control system, the Uxbridge facility will employ a secondary system to contain any potential fugitive emissions from the plant. This secondary odor control system will consist of atomized essential oil. An essential oil is the predominately volatile material pressed from plants. More than 3,000 oils have been identified and several hundred of these have been commercialized. Essential oils have been applied to control odors at landfills, agricultural sites, restaurants, wastewater treatment, and industrial operations. STEP has not directly corroborated the effectiveness of these applications.

Commercial essential oil mixes consist of essential oils, terpenes and their oxygenated counterparts, terpenoids. Where essential oils are atomized on the surface of a fine mist of water droplets, the essential oils act as a physical, electrostatic trap for some odorant molecules. As the oils form a thin film over the water droplet, this "skin" creates an electrostatic charge and attracts charged odor molecules. Where chemical reactions with essential oils are asserted to occur, the principal types of reactions are thought to be oxidation (including fast-acting hydroxyl radicals), reduction and some esterification.

A range of readily available misting equipment may be used to apply essential oil odor barriers. Application considerations require that water droplets are fine enough so that they do not condense and precipitate from the column of air. This is accomplished by forcing a mixture through a fine nozzle. The mixture will contain a suitable carrier (e.g. isopropyl alcohol), water, and essential oil. The amount of essential oil that is applied will depend upon some subjective assessment of need. The need for increasing the application of essential oil (over some baseline rate) will be governed by perceptions of facility operators, first, and external reporters, second.

The specific essential oil that will be used by Bio-Dynamics is a product called Ecosorb®, a proprietary formulation of several essential oils and food grade surfactants. The vendor supplying this product reports an illustration of the product's odor control performance in the table below. While several orders of magnitude in odorant reduction can be generated within 15 minutes, the vendor's application guidelines target a 5 second vapor-to-odorant contact time in an essential oil mist (i.e. 10 u droplets). The mist should obtain no more than 85% relative humidity at the site of odor containment. In rainy weather, maximal odor containment can expect to be somewhat compromised due to condensation of essential oil out of the air column. Rain, itself, however, mitigates some odor problems because many odorant molecules are soluble in water such that rain can act as a natural air scrubber.

EcoSorb® Contact Testing With Identified Gases (ppm/v)

Gases	*Ammonia*	*Hydrogen Sulfide*
Perm Tube	97	48
Reactor Out	97	48
Contact	68	40
5 min	5	7
15 min	<1	<2

Note: this table reports progressive reduction in the concentration of two representative odor types with exposure to a mist of essential oil.

The Uxbridge facility proposal includes provisions for establishing an odor barrier at doorways that allow access into the tipping floor and processing chambers of the manufacturing facility. Opportunities for fugitive release of odor are limited to those times when trucks enter and leave the building. Essential oil treatment is a strategy for managing these episodes.

In applications where essential oils have been used as a primary odor control mechanism, the EcoSorb® vendor reports effective performance for a fish meal manufacturer (in the southern United States) who blends barley, soybeans and fish oil to make a dry fish food. The vendor asserts that using 106 nozzles spraying into a 30 inch flue as well as a 10x10x24 plenum, the fish food manufacturer uses one gallon of Ecosorb® per operational hour. The same vendor also reports that for a California fertilizer manufacturer processing municipal sludge at a 200 acre land fill (an application significantly different from the waste food processing operations proposed in this review), acute odor episodes are controlled with two oscillating fan systems that are automatically activated when vehicles dump their loads. This site is reported to use 55 gallons of Ecosorb® per month. For in-vessel compost manufacturing, the vendor cites an East Coast composting facility (again using municipal sludge) operating in a 90,000 square foot indoor facility. This site is reported to use 1,100 gallons of atomized essential oil per month for complete odor control.

Across a range of applications, essential oil user have offered testimonials to the effectiveness of this as a primary odor management technology. Third party assessments of different dimensions of the performance of EcoSorb® have been offered by:

- Dr. Sylvain Savard, Center of Industrial Research for Quebec;
- Drs.Ying Shang, R.W. Hurd, and Donald R. Wilkinson, Delaware State University; and
- Carter Laboratories, CA

The Safety profile of EcoSorb® has been established through testing performed by Tox Monitor Laboratories, Inc., of Oak Park, IL. Tests performed by this independent laboratory included EPA Guidelines 81-1, 81-2, 81-3, 81-4, 81-5, and 81-6, and found the product non-toxic in all categories (e.g. Toxicity IV for skin effects, Toxicity Category III for eye effects, Toxicity Category IV for acute oral exposure, Toxicity Category IV for acute inhalation exposure, Toxicity Category IV for acute dermal exposure, and no positive Buehler reactions for skin sensitizing effects). The product's MSDS identify is Ecosorb 6()6, and is characterized as stable, milky white fluid with a slight citrus or floral odor and with no fire or explosion hazards.

As a consciously-applied secondary odor control system, the essential oil odor management system of the Uxbridge Facility appears fully adequate to manage fugitive odors as may result from incidental spills or air leaks that might occur within the fully enclosed manufacturing facility. Moreover, if scaled sufficiently, this secondary odor control system may have the capacity to keep the facility odor free for some undetermined period of time in the event that the primary system experienced a failure. STEP sees the combined use of a biofilter and essential oil misting as an effort to go beyond meeting conventional requirements for air quality control for food scrap remanufacturing operations.

***Other Odor Control:* <u>*Best Management Practices*</u>**

- Complete containment of all transfer and processing activities within a building maintained under negative pressure prevents the escape of fugitive emissions. Fugitive emissions are the principal source of odor in many large-scale operations. The proposed ATAD manufacturing facility includes plans to apply best management practice to its odor control program.
- Vacuum transfer and slurry transportation require that transfer vehicles fully contain incoming feedstock. This prevents fugitive emissions during transport to the manufacturing facility.
- Acidified, anaerobic holding tanks to collect up slurry at food scrap production sites minimizes opportunities for odor production and fugitive emissions at the source of feedstock generation. It is STEP's understanding that underground storage tanks will be preferred over current on-site practices for storing food scrap between scheduled waste removal cycles.

TECHNOLOGY APPLICABILITY

Bioconverted organic feedstock derived from food processing, agriculture, domestic refuse, sewage and industrial effluent contain large quantities of organic matter which must be rendered into a form that will not attract vermin, transmit disease or release odor or toxic gases. The in-vessel slurry bioconversion system examined in this study represents one means of managing this problem. The manufacturing system, considered in its entirety, is applicable for converting organic waste into valuable agricultural product. Restrictions on land filling, composting, and odor collectively favor consideration of this technology.

Applicability to Industry/User

The precedent fertilizer manufacturing system technology considered in this report provides advantages over competing organic waste processing technologies through its use of presorted food waste generated by a network of value-added suppliers. Proponents of this approach assert that cleanliness of collection equipment (including routinely steam cleaned, sealed collection vessels and stainless steel fluid transport vehicles) differentiates this service from current garbage collection practices.

The central processing facility has been designed such that it can accommodate up to 20% contamination with plastic, metal, paper and cardboard; however, feedstock supply contracts specify no more than 10% non-digestible material, which is well within the Massachusetts regulatory guideline of 15% maximum residue allowed in the incoming material. Non-digestible contaminates are screened from the slurry during processing. As a result, the finished product has uniform physical characteristics (e.g. texture and fiber content) that add to its value in subsequent soil or fertilizer manufacturing processes that require component blending.

In independent tests conducted by BC Research, Inc., product produced by IBRC (the precedent soil manufacturing facility for the technology described in this report) has been demonstrated to stimulate 30% more plant growth than leading commercial chemical fertilizers currently in the market. This performance claim, however, has not been benchmarked against alternative composting products. International Bio Recovery Corporation indicates that the product is a complete growth media that can be used as fertilizer or can be used as “an organic base for chemical fertilizers” (page 27, Final Prospectus, Sept 29, 1998. Brink, Hudson & LeFever, ltd., Vancouver, BC).

Proponents for the fertilizer manufacturing process examined in this study assert that the process provides a throughput cycle time of approximately 3 days, compared to 20 to 60 days for windrow composting. This is accomplished by digesting waste at temperatures between 60 ^{o}C and 80^{o}C through heat generated by microbial action. Rapid, aerobic cycle times minimize opportunities for anaerobic processes to generate odors and opportunities for vermin to be attracted to feedstocks.

The manufacturing technology, based upon aerobic methods, avoids the production of methane. Thus, approximately 75% more of the nutrient value of the processed organic material is retained in the finished product and made available to beneficial reuses. Odor and explosion risks associated with handling methane production are avoided.

While the IBR ATAD manufacturing process is more capital intensive than windrow composting, proponents assert ATAD to be cost-competitive with in-vessel composting principally because more rapid throughput improves the return on investments made into more capital intensive systems. STEP has not completed a full cost comparison across competing technologies primarily because such a comparison must be based upon strong assumptions about the requirements of each specific processing site (see “Economic Model”).

TECHNOLOGY APPLICABILITY

Development/Application History

From January 3, 1993 through May 30, 1998, the manufacturing technology discussed in this study was being developed by International Bio Recovery Corporation, North Vancouver, British Columbia, Canada. IBRC reports costs of $3,560,000 (Canadian) for developing the process and service and $480,000 (Canadian) for developing the product. Innovations principally include adding feedstock pre-sorting processes and redesigning the aeration and foam cutting processes. Refinements include de-watering and drying equipment, and process monitoring and control techniques.

The manufacturing system plans examined in this study have been generated by Uxbridge Food Processors LLC, a joint venture of Bio-Dynamics and International Bio Recovery Corporation. Bio-Dynamics is contributing business relationships to provide and haul waste scrap and to negotiate and secure permits for facility sites. International Bio Recovery Corporation is contributing the technology, and currently operates a commercial scale facility based upon this technology at 52 Riverside Drive, North Vancouver, British Columbia. Bio-Dynamics' operations at the Uxbridge site will be managed by the Roy F. Weston Corporation (see details under Lessons Learned / Implementation Issues, page 33).

Lessons Learned During Technology Development

1. Aeration is a critical control aspect of the ATAD process, and application of a means of introducing fine bubble diffusion contributes to advantageous fermentation reactions. The IBR ATAD process proponents assert that the use of Shearator™-type submersible aerators enhances aeration and reduces equipment O&M costs by 40%. The IBR proponents assert that agitation and aeration of a slurry of 10% food waste solids require much more energy than liquid or domestic waste.

2. Slurry digester design and feedstock presorting play key roles in facilitating sieving grit and debris from the feedstock and microbial biomass product stream. Pre-sorting and pre-processing methods that avoid shearing plastic and particulate debris facilitate removing non-bioconvertable material from the feedstock stream. Excluding metallic items (i.e. flatware and metal containers) at the source of food waste entry into the feedstock minimizes occlusion of plastic and small particle filters during subsequent steps of the manufacturing process.

3. Odor management is simplified through improved ATAD management. The need for odor management under average operating conditions is fully addressed with biofilter systems processing 80,000 m3/d of vented digester gases and 1,000,000 m3/d of air exhausted from the building housing the transfer and processing operations. Literature reports indicate that odor release episodes are most likely to occur when odorous materials are being transferred outside of effective odor capture containment, and biofilter site examinations indicate that odors are more likely to issue from fugitive emissions of air scrubbers than from biofilters themselves. Optimal odor source control is achieved by making feedstock and process fluid transfers only within fully enclosed, negative pressure facilities. The Vancouver facility discovered that heavy rains could compromise the performance of its initial biofilter and lead to odor problems. Using this knowledge, the Vancouver group improved biofilter design and now asserts that the resulting improvements have resulted in complaint-free operations over a 2-month evaluation period.

4. ATAD systems generate little free ammonia, even though it is recognized that at temperatures above 45^{o}C microbial nitrification is inhibited. This phenomenon is explained as a result of excess ammonia-nitrogen reacting with carbon dioxide in solution to produce ammonium bicarbonate (Stover, 2000, page 32).

TECHNOLOGY APPLICABILITY

Benchmarking ATAD Systems

ATAD systems are robust and reliable processing systems that require limited specialized operating skill. The EPA has examined such systems in depth, and, in this analysis, key features of those systems are compared with elements of the IBR ATAD manufacturing system design (see table below). The table shown below compares the IBR ATAD fertilizer manufacturing system with EPA data on ATAD systems used to process sludge. The point of the comparison is to illustrate the extent to which the IBR system builds upon technologically systems and practices with well-characterized performance histories.

Benchmarking ATAD-based Process Facilities for Processing Cycle Time			
Comparable ATAD Process Facility	**Subject**	**Comp. 1**	**Comp. 2**
Site	**Vancouver**	**Nette**	**Romersberg**
Vendor	IBRC	Fuchs	Thieme
Size (Population Equivalent)	125,000	80,000	18,000
Design loading (kg/d)	8,000	3.040	840
Feed volume (m3/d)	100	76	21
# of reactors	9	2	2
Dimensions (dia., ht. In m)	NA	NA	NA
Active volume @ m3	600	180	48 + 24
Standard Retention Time (days)	3	4.7	3.4
Volumetric Loading (kg/d/m3)	13.3	8.4	11.7
# of aerators per reactor	NA	3	1
Installed aeration power (kW)	**505**	39	16
# of foam cutters per reactor	NA	4	NA
Installed foam cutter power (kW)	100	4.5	NA
Total installed power (kW)	605	43.5	NA
Power density (W/m3)	1000	121	NA
Daily power use (kW/day)	**14,520**	1,044	NA
Specific power applied (W/kg VSS)	NA	343	NA
Years in service	(since 1994)	(since 1984)	(Since 1985)
Percent of capacity	38%	NA	NA
Types of waste (Domestic/Industrial/Food)	Dom / Ind /Food	Dom 50%	Dom / Ind
Types of sludge (Primary / Activated waste)	(P & A)	P & A	P & A
Feed solids (%)	0.0 – 40.0	5.7	7.9 – 10.0
Feed Frequency (per day)	1	1	0.42
Isolated reaction time (Hr)	NA	23	56
R1 temperature (C)	55	42	45
R2 temperature (C)	75	56	55-70
Post thickening % solids	Dry to 92%	Up to 7 %	NA
O&M time required (Hrs/wk)	NA	2	NA
Odor Control system (Installed/not)	Installed	Installed	Installed
Maintenance tests (i.e. cleaning / repair)	Aerator maintenance	Aerator maintenance	Aerator maintenance

- 4410 Kg/ton = 2.205 kg/lb. * 2000 lb./ton
- Municipal ATAD design loading calculations are based on an average of 4% VSS concentration
- Processed Food Slurry Feedstock calculations are based on an average of 9% TSS concentration
- VSS is assumed herein typically to be 75% of TSS (page 14, EPA 625/10-90/007)
- IBRC Subject Site (with daily loading of 200 ton/day slurry @ 9% TSS) = 80,000 kg/d TSS
- Nette Municipal Site (with 3,000 Kg/d VSS) = 2,250 Kg/d TSS (or 1/35th subject scale)
- Romersberg Municipal Site (with 840 Kg/d VSS) = 630 Kg/d TSS (or 1/127th subject scale)

TECHNOLOGY APPLICABILITY

STEP finds the IRB facility and the proposed facility to conform to the design features of typical ATAD operations, with the specific enhancement of aeration. It is understood by STEP that the increased aeration (and energy costs associated with this aeration) is one of the key features that improves the use of ATAD technology for the proposed manufacturing purposes. This enhanced aeration technology is based upon patented technology and proprietary designs of the IBR Corporation and is beyond the scope of this report.

ATAD technology has advanced over the decade since the US EPA last formally examined it. Innovation is reflected both by patents that have issued in the field (see below) and new products that have appeared on the market. Patents included both radical and incremental innovation of the ATAD process (note: a radical innovation is represented by in-process slurry screening such as is embodied by improved digester design). Incremental innovations appear as "new and improved" features of subsystems currently in use in ATAD facilities. An example of new and improved subsystems entering the market is illustrated by submersible mixer advances that promote improved energy efficiency and reduced repair times (e.g. 5 fold increase in motor life; U.S Filter's EMU Products Group, Thomasville, GA). The appearance of incrementally improved products suggests that there may be additional efficient benefits to be captured in ATAD systems. Incremental efficiency innovations appear well suited as retro-fits to ATAD systems.

Representative Recent Patents Illustrating Continued Process Evolution

1999	Process for Treating Biosolids from Wastewater Treatment (US 5948261) Richard L. Pressley, Crown Point, IN. Improved temperature control through adjusting shear generated through jet aeration devices.
1999	Thermophilic Aerobic Waste Treatment Process (US 5885448) Kenneth L. Norcross & Yanlong Li, Edwardsville, KS. Improved processing efficiency through injecting into the digestion chamber a mix of fresh and recycled reactor air.
1998	Process for Thermophilic Aerobic Fermentation of Organic Waste (US 5810903) Rene Joseph Branconnier et al, Ontario, Canada. Process for Thermophilic Aerobic Fermentation of Organic Waste. Improved processing efficiency through mixing, enzyme treatment, pre-heating, and continuously mixing in-inoculated feedstock into a reactor containing active aerobic thermophilic microbes.
1998	Process and Apparatus for Liquid Sludge Stabilization (US 5851404) Richard W. Christy & Paul G. Christy, Wayne, PA. Gravity flow design that minimizes the need for mixing in order to move material through the ATAD process.
1997	Waste Conversion by Liquid Thermophilic Aerobic Digestion (US 5702499) Hubert J. Timmenga, Vancouver, Canada. Establishing monitoring parameters to determine stages of processing when the majority of organic nutrient has been consumed without significant consumption of lignin or cellulose.
1992	Method and Apparatus for Improving Efficiency of Fluid Use and Odor Control in In-Vessel Composting Systems (US 5175106) John G. Laurenson, Jr., St. Augustine, FL. Recycled fluid and air streams improve operating efficiency and improve odor containment.

TECHNOLOGY APPLICATION

General Setting

The IBR plant located in North Vancouver, British Columbia, is a commercial operating facility handling 100 tonne per day of mixed biodegradable material collected by commercial haulers from more than 50 different generators; i.e. food processors, restaurants, supermarkets, fish processing facilities, hospital kitchen waste, hotels, etc. This plant produces six (6) tonnes of solid fertilizer and six (6) tonnes of liquid fertilizer. The Plant is located on a two (2) acre parcel of land located in the light industrial area adjacent to residential facilities. STEP has not reviewed factors or plans that influenced IBR siting decisions.

Technology Implementation at a Manufacturing Plant Site

A simplified footprint of the IBR facility layout is not publicly available at this time. The sequential location of process systems within the manufacturing plant is illustrated in a block flow diagram shown on page 9 of this document. The specific model and brand identification of the major equipment required of manufacturing process is not offered as public information at this time.

Material which does not enter the facility as a slurry arrives on tipping floor for inspection where large, unprocessable materials (i.e., wood pallets, cardboard boxes, etc.), if present, are removed by hand. Bio-Dynamics' proposed facility in Uxbridge has a specific prohibition against "unprocessed meats" as fertilizer feedstock, and such material will be rejected and returned to haulers for disposal at their expense. Accepted material (if not already in a slurry form) is placed in a macerator where it is slurried to a 8-10% solid content, consistent with incoming slurry feedstock. During maceration (also referred to in this document as "pulping"), plastics, fabrics, particulate metals, gravel and other heavy material are mechanically separated. The slurry is then pumped into a primary digester, heated to a minimum of 55ºC and inoculated with bacteria produced in the previous batch. During its 48-hour stay in this digester, glass and sand etc. are removed through sedimentation. After this process, the "unders" (material below the foam layer within the digester) from this partial digest are pumped into a secondary digester for a further digestion of 24 hours. The "overs", small Styrofoam, plastics, etc., are pumped into a rejected digester where they are further digested and separated by a proprietary mechanism. Digested material from the reject digester rejoins the process flow in the secondary digester. Sieved, unprocessable debris is sent to landfill facilities. The digested slurry is partitioned by a rotary press into a solid cake having a ~50% solid content and a filtrate having a ~2% soluble solid content. The solids are further dried in a non-contact dryer, pelletized, crumbled, screened into three fractions and baked. The liquid goes through a final settling process after which it is concentrated to a 35% solid content and bottled. Before pelletization or evaporation, and based upon manufacturing requirements, organic additives may be added to the final product stream to produce fertilizers to meet specific growers' demands.

TECHNOLOGY PERFORMANCE

The objective of this manufacturing facility is to enable a cost-effective, ATAD-based microbial conversion of waste food feedstock into microbial biomass fertilizer product, without objectionable odor. The technology's performance in the selected application is described by summarizing the application runs made and the performance achieved.

Performance Goals

Environmental Goals

- The IBR technology will not have any negative effect on the environment.

- The IBR technology at the Uxbridge facility will be able to handle 200 tons per day of mixed food wastes with up to 10% inorganic, unprocessable material, and convert this material into a high quality fertilizer.

- The IBR technology will accommodate urban operations within a small facility footprint, with a rapid waste conversion cycle, and within a safe, stable and odor-contained operating environment.

Facility Performance Goals

- Solid food scrap waste received at the plant (with an initial average solid content of 15%) will be converted into high quality end product with an average loss of no more than 2% of incoming solid organic mass. Total solids in all end product (representing 13% of the incoming 15% solid matter) will exist as stabilized liquid product (9.8 ton of liquid fertilizer at 67% moisture content from 100 tons of feedstock slurry) and as stabilized dry product (10.6 ton of solid product is products with an 8% moisture content from 100 tons of feedstock slurry). No "unprocessed meats" will be accepted as fertilizer feedstock at the Uxbridge facility.

- The IBR process will demonstrate itself to have among the highest yield and fastest food waste fertilizer manufacturing cycle time (between 54-72 hours compared to conventional ATAD systems of 10 days), and will be targeting a product yield of better than 85% throughput on a solid mass basis and a decrease of cycle time by 70%.

- Facilities using the IRB process will manage vapor/air emissions to be in compliance with the most stringent air quality emission regulations.

Product Performance Goals

- Fertilizer produced by the IBR ATAD process will offer cost-comparable or superior crop growth while concurrently significantly reducing requirements for added phosphorous, inorganic nitrogen, insecticide and/or fungicide.

Technology Application Test Cases

Performance tests run during the application of ATAD for fertilizer manufacturing include monitoring temperature over time, and for tracking solids content in product. A range of feedstock types has been examined by IRB over the course of its operations. Representative data from processing food waste scraps is shown below.

TECHNOLOGY PERFORMANCE

cycle number	pulp (tonnes)*	% solids	Liquid Product	% solids	Dry Product	% Solids	liquid yield	dry yield	total yield	Cycle time
812	66	9.2%	4.2	35%	4.1	95%	24%	65%	89%	N/A
813	65	8.4%	4.4	35%	3.9	95%	28%	68%	96%	91 hr
814	65	7.8%	3.9	35%	3.4	94%	27%	63%	90%	N/A
815	65	8.0%	4.1	35%	3.4	95%	28%	62%	90%	67 hr
816	65	8.4%	4.2	35%	3.7	94%	27%	64%	91%	91 hr
822	64	7.0%	3.9	35%	3.0	95%	30%	63%	94%	67 hr
826	64	7.2%	3.9	35%	3.0	95%	29%	62%	91%	67 hr
Avg.	65	8%	4.1	35%	3.5	95%	28%	64%	92%	77 hr
S.D.	0.5	1%	0.2	--	0.4	0%	2%	2%	2%	--
CoV	1%	9%	5%	--	12%	1%	7%	3%	3%	--

* incoming volumes of 60,000 liters per batch are converted to approximate mass using reported solids content

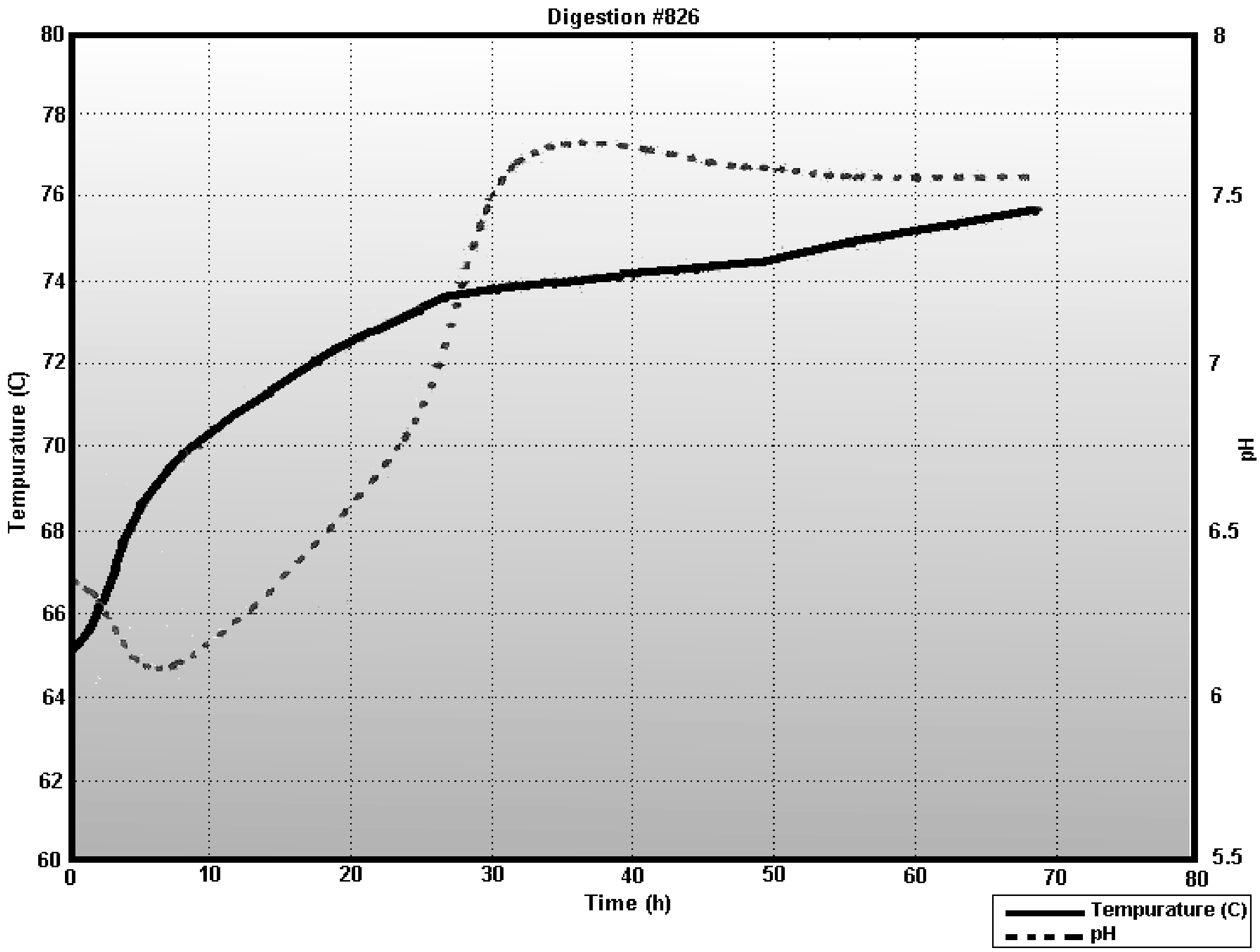
** "Reject volumes" average 0.2 tonnes at 45% solids.

(S.D. = standard deviation; CoV = coefficient of variance; N/A = not available)

Throughput is reported to be consistent with a high product yield on a feedstock dry weight basis. Production cycles average 77 hours, however the distribution is distinctly bimodal, taking either just under three or just under 4 working days. This is because the end of the digestion cycle is gated by opportunities to begin daily post-digestion work cycles within the Vancouver manufacturing plant. In general, around 9:00 a.m., and if a given reactor meets criteria, the digestion phase is formally terminated and the digester contents are moved to de-watering equipment. Data points represented by *N/A were reactions where substitution of worn components were replaced "on the fly." Because these batches were atypical due to insertion of maintenance activity during the production run, they were not included as data typical of production runs in this analysis.

STEP has not conducted a direct assessment of the consistency of end product across successive batches of ATAD processed food waste scrap.

Digestion process is monitored principally with reference to temperature and pH. Representative temperature (solid line) and pH (broken line) data for a waste food scrap digestion run are indicated in the figure below. IBR has a proprietary means of interpreting the monitoring data from which, IBR asserts, batches of feedstock can be manufactured into fertilizer with consistent physical and chemical properties.



Technology Application Results

The application results from the IBR manufacturing facility are reflected in the quality of product generated by their process when compared with the quality of product produced by other processes. STEP has examined representative end product produced at the IBR facility for texture and odor, and STEP finds that the product has a dark brown color, an easily turned fine granular texture in the powder form (or slightly viscous fluid property in the liquid form), and a slight humus-like odor. An analysis of the full agricultural performance of the end product generated through the application of the ATAD process is beyond the scope of this report. However, claims for the merit of the product generated through the IBR process have been issued through independent analysis performed by BC Research Inc. (BCRI) under contract to IBR. In a confidential BCRI report dated August 11, 1994, which has been examined in the course of preparing this report, the following findings were reported (partial list of total table of findings shown below):

TECHNOLOGY PERFORMANCE

Comparative Fertilizer Value of IBRC's Organic Fertilizer, Commercial Composts, and Commercial Organic Fertilizers.			
Type of Fertilizer	% Nitrogen	% Phosphorous	% Potassium
IBRC End Product (not spiked)	4.1	1.0	1.5
Digested MSW	0.8	0.03	0.4
Cow Manure / Bedding (Fertlife™)	1.0	1.0	1.0
Worm Castings	1.6	0.1	0.02
Bone Meal / Dried Blood (Garden Food™)	5	5	5
Dried Sewage (Milorganite™)	6	2	0

This same study characterizes the stability of the product by monitoring the reduction of biochemical oxygen demand (44% reduction) and chemical oxygen demand (31% reduction) of the slurry to the point where it is de-watered for packaging or bottling.

BCRI additionally monitored the nitrogen, phosphorous and potassium (N-P-K) ratios within the pulp before digestion (1-0.24-0.43), after 36 hours of processing (1-0.25-0.45), and within end product before end product was spiked with mineral salts (1-0.24-0.36; recalculated from their reported data). The constant nitrogen to phosphorous ratio is interpreted as evidence for no limited loss of nitrogen during processing, which corroborates the proponents' claims that the ATAD manufacturing process is odor-free when applied to food scrap feedstock.

A second independent assessment reviewed by STEP (i.e. excerpts of a study conducted by Mikrotek, Ontario) compared IBR product (6-2-4 N-P-K with 57% organic matter) with a commercial fertilizer (19-25-5 N-P-K with 1.8% sulfur) manufactured by Scotts. In this study, no statistically significant difference in the growth of golf course grass was observed. STEP interprets this data as indicating comparable agricultural performance with 8% of the phosphorous load and with 30% of the inorganic nitrogen content of the commercial product.

On the basis of material reviewed by STEP, STEP concludes that the IBR end product has genuine value as a fertilizer.

Performance Compared to Existing / Traditional Technology

The use of ATAD as a fertilizer manufacturing process can be compared with alternative means of generating soil amendment. Such alternative methods include solid state bioconversion in the form of exposed windrows or in-vessel, aerated solid stacks. Because odor containment is a key requirement of urban fertilizer manufacturing, comparisons among in-vessel bioconversion systems are most meaningful.

Generic categories of contained composting systems include:

1. Tunnel Reactors – (e.g. Double-T Equipment; Kelly Green Environmental)
2. Rotating Drums – (e.g. BW Organics Greendrum; Augspurger Engineering)
3. Agitated-aerated Containers (e.g. Earth Tub; Wright Environmental Management)
4. Aerated Containers – (e.g. CMT Comptainer; NaturTech; Stinnes-Enerco; Ag-Bag Env.)
5. Agitated Beds – (e.g. US Filter IP; Longwood Manufacturing; Transformer Compost Systems; Resource Optimization Technologies (ROT) Box)
6. Passive Aeration – (e.g. TEG silo-cage & twin-cage; Bins Hot Box)

Leading firms advocating very large scale in-vessel composting technologies include Bedminster, Raytheon, Salsem Veciap, ASP, American BioTech, Wright Environmental, and Reidel (source: EPA

MSW Factbook). The ease and the extent to which aerobic conditions can be maintained in these systems are open to debate. Oxygen diffusion into, and retention within, an active biomass requires diffusion through a liquid interface. The water content within these solid phase systems is important for aerobic microbial respiration, and optimal microbial respiration is needed for aerobic physiological activity.

Large-scale slurry phase treatment projects have been piloted at Joliet Army Ammunition Plant (1992), the Navy Weapons Station at Seal Beach, CA, and the EPA Test & Evaluation Facility in Ohio. Open lagoon slurry composting practices (a traditional agricultural approach) rapidly become anaerobic. Large scale, in-vessel slurry phase treatment is typical of anaerobic digestion within SWM facilities (see Tchobanoglous, G. and Burton, F.L for an overview of these reactor designs). Anaerobic SWM facilities typically have 30 to 60 day detention times. In some facilities, aerobic slurry treatment provides a front end feature of some MSW facilities, where the aerobic subsystem serves to improve thermal sterilization of pathogens, remove volatile solids, and reduce odor.

While solid-phase, in-vessel composting is offered by some vendors for small-scale operations (e.g. Green Mountain Technology's static Earth Tub and Texas A&M's and Spectraserv Inc.'s rotating drums), small-scale liquid phase (slurry) composting systems appear currently unavailable.

STEP has not concluded a comprehensive cost comparisons among solid-state and slurry in-vessel organic waste conversion systems. Elements that might be included in such a comparison are land cost, building cost, compost bays or digesters, press wheels, aeration systems, turning equipment or pumping systems, monitoring systems, heating systems and evaporators, cardboard and product pelletizers, bagging, bottling and storage systems, odor control systems, operations and maintenance costs, and product evaluation and marketing costs. Generic comparisons are illustrated in the table below.

Tabular Comparison of ATAD and Traditional Organic Waste Processing Technology		
	ATAD	*Traditional Composting*
Productivity (yields)	Over 20% product yield on a wet weight basis	N/A
Product quality (note if there are changes - improvements or deterioration)	Improved micronutrient content, and physical properties (free of glass shards)	Depleted nitrogen, odorous, fibrous, glass and metal shards
Raw materials required (types and microbes, nutrients, odor-controlling chemicals, etc.)	pH control, temperature control, polymer bulking	C-N balancing, wood chip bulking, temperature control (turning)
Utility requirements (water, steam, electric power, transportation costs)	Hauling, heat, air flow, fluid mixing-pumping, building utilities, packaging, shipping	Hauling, mechanical turning, bulk shipping
Wastewater, solid waste, and air emission	Air quality control, water quality control, odor control	Leachate control, odor control, vermin control
Improved rinse efficiency	Discharge of 680 liter per ton of clean condensate, no disposal charges	N/A
Volume of waste sent to offsite recycling	Removal of up to 20 % non-processable debris from the feedstock, requires a presorted feedstock compliant to QA/QC management	Limited removal dependent upon feedstock source (accommodates many feedstock types, but must balance carbon and nitrogen to process)
Odor control	Continuous and complete control	Episodic control, season issues

COST INFORMATION

Capital Costs

Representative costs of different types of ATAD facilities have limited application where such facilities must process different types of incoming organic material and where such facilities operate at radically different throughput scales. For purposes of forecasting key costs related to ATAD systems, the table below compares key capital costs categories. While waste processing and fertilizer manufacturing facilities can be expected to have distinct operating constraints and cost factors, they clearly share the need to basic enabling components and sub-systems.

ATAD System Component Comparison			
Component	*Number*	*Vancouver IBRC*	*System 2 cost Thieme*
ATAD digesters	N/A	Yes (capped, steel)	Yes (concrete)
Aerators	N/A	Yes	Yes
Foam cutters		Yes	N/A
Piping		Yes	Yes
Electronic controls		Yes	Yes
Exhaust blower		Yes	Yes
Aeration blower		Yes	Yes
Feedstock transfer pump		Yes	Yes
Thickening tank		No	No
Concrete slab for reactors		No	Yes
Biofilter		Yes	--
Total Start Up Costs		$ ----------------	--
Total Annual Costs/100 tons		$ 850,000	N/A

Operating Costs

The following cost item estimates apply to a 240 tonne facility (in Canadian dollars):

- Labor including training and license requirements for supervisors and operators (using fully burdened rates) is estimated at $120,000 / month
- Utilities and special provisions (e.g., electricity, fuel, steam, water, air, space requirements, fire protection, safety requirements, onsite laboratory requirements) are estimated at $54,000 / month
- Maintenance costs is estimated at $15,000 / month
- Waste disposal (landfill) expense is estimated at $15,000 / month
- Materials (lime, polymer, miscellaneous plant supplies) costs are estimated at $ 11,000 /month
- Laboratory costs are estimated at $1,200 / month
- Depreciation charges vary from 3 to 20 year amortization schedules, with a nominal 20%
- Water and sewer expenses is estimated at $6,000 / month

The operating cost data for the Uxbridge manufacturing facility is a proprietary aspect of their business plan and is beyond the scope of this document. Costs will reflect local costs for labor, utilities, construction, and financing. For this reason, costs associated with the application of the technology under review by STEP cannot be reported in a generic form. For a more complete explanation of the limitations on projecting costs for this technology, see the section on “Economic Model.”

COST INFORMATION

Cost Benchmarks

This section is intended to provide details regarding cost benchmarks that illustrate benefits derived from the application of ATAD technology to the fertilizer manufacturing process, specifically in terms of the costs benefits for receiving and processing organic waste feedstock and cost benefits for sale of premium fertilizer for consumer markets and for chemical fertilizer manufacturing markets.

Current market data indicates a nominal waste producer cost of $ 60 per wet ton for hauling and disposal of organic waste within the Commonwealth of Massachusetts, with a range from $45 for source separated produce waste processed at a composting facility up to $100 for wastes from manufacturing facilities. STEP has confirmed the pressing and enduring need for organic waste disposal, and specific pressing needs for improved disposal options for fats, oils and greases.

The estimated manufacturing costs to collect and haul food processing type waste to an ATAD fertilizer manufacturing facility should be based on a cost per hour. This approach takes into account the disparity among points of supply that have varied access to interstate highways. Total costs to truck are in the range of $60 to $75 per hour. This range accounts for the differences in labor rates, the capital costs of specialty equipment, and fuel consumption variables. The variable costs to operate should be about $35 to $45 per hour. The estimated unit cost per ton to supply the manufacturing facility will range from a high of $30 per ton to a low of $5 per ton. This estimate is based on minimum loads of five tons and maximum loads of fifteen tons with likely haul radius not exceeding 50 miles. Furthermore, no unusual loading or unloading characteristics have been considered.

Market trend data for retail value of compost is strongly dependent upon the quality, and perceived quality, of the specific compost product. Private and commercial organic gardeners may best represent current market demand for premium grade compost. Such a market may pay $ 20 per 40-pound bag of dry product, however, volume discounts are to be expected for large commercial purchases. At this time, the largest recognized existing commercial market for premium grade compost is the nursery fertilizer industry. Fertilizer manufactures familiar with the IBR product appear willing to spend upward to $ 200 per ton for premium grade product that is compatible with their current product blending systems.

ATAD facility benchmarks are illustrated in the table shown below. The initial three entrees represent municipal ATAD wastewater treatment plants (in 1990 dollars from EPA /625/10-90/007, September, 1990), while the fourth entrees represents the only known precedent application of ATAD for fertilizer and/or animal feed filler manufacturing (in 1999 dollars). Benchmarking considers only the primary business objective of providing a product treatment service without reference to costs for producing a commercial sellable product as a secondary business objective.

	Year built	*1990 dollar cost (construction)*	*Throughput (kg dry weight/d)*	*1999 Retail Price ($/kg)*	*1990 Treatment Cost ($/kg)*
Nettetal, FRG[1]	1983	330,000	2540	NA	130
Fassberg, FRG[1]	1981	318,000	1600	NA	199
Romersberg, FRG[1]	1984	321,000	900	NA	357
Uxbridge, MA	planned	~ $9,500,000	800	~ $1	~ $ 0.07 *

Note[1] Data taken from EPA /625/10-90/007, September 1990.

Note[2] Re-calculated from confidential 1999 IBR data based upon a zero product sales assumption (a 240 long tonnes capacity requires $441K in fixed and variable operating costs [exclusive of royalties, fees, capital and depreciation] per month yields a calculated unit processing cost of $441,000/243,854 kg wet weight, or $1.80/kg, in 1999 dollars).

COST INFORMATION

Note* 1999 US Dollars. STEP understands that the cost structure for the use of ATAD for food scrap re-manufacturing is radically different from the cost structure for waste water treatment principally because waste waters arrive at treatment facilities with a nominal 2% to 3% solids content, and must be concentrated to a 6% to 8% content before ATAD can become self-sustaining. Typically, the pre-treatment times required to bring waste water organic content up to operating levels extends the overall treatment cycle to 10 to 12 days of processing.

Economic Model

The limitations of cost comparisons between sites of potential application are best understood by considering the economic model upon which the ATAD manufacturing business is based. The commercial opportunity for ATAD re-manufacturing of food wastes is driven primarily by

1. rising costs for hauling and disposing organic waste,
2. continued closing of landfill disposal sites to organic waste, and
3. requirements for nuisance-free waste management technologies in urban settings.

Food scrap waste management options (which, in an economic model, include re-manufacturing technologies) are driven both by issues of the scale of the disposal operation and the requirements of individual operating sites. Any capital-intensive disposal (or re-manufacturing) operation must consider the persistence of its supply of feedstock (so that the facility can maintain a year-round operating cycle) and the expense related to getting the feedstock to the operating site. Continuity of the supply of food scrap is dependent primarily upon population and the distribution of population across any specific service area. An assumption must be made that an existing supply of food scrap remains available for the disposal facility (this is analogous to any business making a forecast of the amount of market share it can capture). At this moment, the relatively few recognized and practical options for food scrap disposal within urban reaches of the Commonwealth favors the consideration of innovative disposal (re-manufacturing) technologies. With regard to the proposed operation in Uxbridge, the ATAD manufacturing facility currently stands to capture a dominant share of the available food scrap from within its hauling region. The hauling region for any disposal operation is largely defined by expectations to capture AND RETAIN a sufficient volume of feedstock to efficiently use whatever capital assets are installed in the manufacturing facility. The reasoning is, of necessity, a bit cyclic. The objective is to balance the equation to reach a desired cost structure (while remaining within other design parameters). The Uxbridge facility has been designed to operate at a nominal processing cost of less than $ 32 per ton of food scrap slurry with 10% solid content (exclusive of equity and financing costs) under safe and nuisance-free conditions. Precise details about capital expenses for startup and details about financing arrangements are proprietary aspects of Bio-Dynamics' business plan, and are expected to be rigorously reviewed by prospective investors. If new, alternative food waste disposal (or re-manufacturing) technologies emerge within the specified hauling region, the Uxbridge facility may or may not be able to capture sufficient market share to sustain its operations (on the basis of disposal fees alone). The scale of the facility design represents a forecast of available feedstock, and failing to capture and retain this feedstock represents the principal business risk.

The Uxbridge food scrap re-manufacturing facility (the fertilizer manufacturing facility) is hedging its business risk because it has a second revenue stream in the form of sales of its end product (for which there will also be marketing costs). At this time, revenue forecasts from the sale of end product have (in STEP's view) been conservative. The Uxbridge facility is scaled to serve a hauling area sufficient to generate enough revenue to operate at a profit solely on the basis of fees charged to receive food scrap waste. For this reason, if the market for end product collapses, fails to develop, or under-performs, the core operations of the facility are not threatened. The business model of the Uxbridge facility is, however, threatened if food waste disposal practices change in a way that makes shipping the food waste to the re-manufacturing site economically unattractive. If, on the other hand, economic conditions increased the appeal of shipping food waste to the re-manufacturing site, the profitability of the venture would improve.

There is limited capacity (estimated at no more than 50%) for expansion of operations beyond those specified by the current facility design. Because of physical limits of the Uxbridge site, costs related to transportation, and limits set by regulatory permits, proponents of ATAD manufacturing of food wastes would need to seek to capture opportunities created by any substantial increase in regional demand for its disposal service by replicating its Uxbridge facility at additional sites (where hauling costs can be minimized). STEP is not offering a view of the attractiveness of the business venture from an investor perspective (there are considerably different risks associated with such a consideration). Rather STEP is offering a view of the expected stability of the proposed Uxbridge operation in the context of reasonably anticipated business risks. The proposed Uxbridge facility appears to face business risks typical of many manufacturing operations dependent upon bulk transport of critical feedstock. This risk, however, is mitigated by the fact that some comparable form of (disposal/re-manufacturing) activity MUST be made available to businesses across the Commonwealth.

REGULATORY/SAFETY REQUIREMENTS

Anticipated Regulatory Requirements

<u>Solid Waste Management</u>

This section presents an overview of the Solid Waste Management regulatory process, and summarizes some procedural and technical requirements. Solid Waste Management facilities in the Commonwealth of Massachusetts are regulated under the provisions of the Massachusetts General Laws (MGL) Chapter 111, Section 150A, and the regulations promulgated thereunder at 310 CMR 16.00 "Site Assignment Regulations for Solid Waste Facilities" (Site Regulations), and 310 CMR 19.000 "Solid Waste Management Facility Regulations" (Facility Regulations). The Site Regulations pertain to the process for deciding whether a parcel of land is suitable to serve as a site for a solid waste management facility. The Facility Regulations on the other hand are intended to comprehensively regulate the storage, transfer, processing, treatment, disposal, use and reuse of solid waste in Massachusetts.

The Applicability section (310 CMR 16.05) within the Site Regulations considers the range of operations involved in the handling or disposal of various types of waste, and the processing of reusable material, in order to determine which type of activity is subject to site assignment as a solid waste facility. In addition, this section also provides the requirements for certain types of recycling, composting, and other operations and activities that are either categorically exempt or conditionally exempt from these regulations, and therefore do not require site assignment.

Certain other recycling and composting operations which do not fall under the categorical exemption or conditional exemption would be subject to "Determination of Need for Site Assignment" (DON) Process under section 16.05(6). The DON review process has been established for facilities handling source separated materials, but having a wider range of accepted materials and potential site locations. In these cases, the proponent will have to apply to the Department for a decision on whether or not a site assignment is necessary. Composting of unprocessed meat and fish wastes, and sewage sludge are not eligible to apply for DON.

The criteria by which the DON decision is made include, but are not limited to:

- Whether the material is pre-sorted, is not mixed with solid waste and is not contaminated
- Whether the material meets the definition of a recyclable or compostable material
- Whether the material can feasibly be processed and recycled under the proposal
- The maximum amount of residue allowed from processing the material is also regulated to ensure that excess solid waste is not being accepted
- Materials are handled in a manner which will not cause nuisance conditions, and will ensure protection of public health and safety, and the environment
- The end product material is marketed for reuse and not disposed

Based on the information reviewed in this document (and specifically with reference to using presorted food waste with less than 15% other residue in the feedstock and excluding sewage residuals), the Massachusetts Department of Environmental Protection believes that the proposed Autothermal Thermophilic Aerobic Digestion (ATAD) process technology would fall under the DON review process under 310 CMR 16.05(6). In the past, the Department issued a DON for a facility using similar technology. A final determination of applicability will be made when the proponent submits permit applications. The DON review process requires that the proponent submit a DON Permit Application (BWP SW 02) to the Department for review and approval, and a copy to the local Board of Health.

REGULATORY/SAFETY REQUIREMENTS

If the proposed project receives the DON approval from the Massachusetts Department of Environmental Protection, then the MEPA process, as it relates to the Review Thresholds for Solid Waste Management facilities would not apply to this project. Therefore, the project proponent would not be required to apply to MEPA for either an ENF or EIR, as far as Solid Waste MEPA review thresholds are concerned. The new MEPA Regulations (dated July 1, 1998) state in part: “New Capacity for storage processing (would require an ENF or EIR) unless the Project is exempt from site assignment requirements.” However, other MEPA Review Thresholds may still apply to this project.

The residue generated from the operations of the proposed facility would be considered solid waste and/or “residuals”, and can either be disposed off in any DEP approved solid waste landfill or a residuals landfill.

MEPA Review

The Massachusetts Environmental Policy Act (MEPA), MGL Chapter 30, Sections 61-62H, is administered by the Secretary of the Executive Office of Environmental Affairs (EOEA), and by the MEPA Unit within EOEA. The regulations implementing MEPA are promulgated at 301 CMR 11.00. A brief overview of how the MEPA process interacts with the Department’s Solid Waste Management Regulations is presented below.

The purpose of the MEPA process is to examine the environmental impacts of a project, look at the impacts of alternatives to the project, and provide the public and interested organizations an opportunity to comment on the proposed project. The MEPA process applies to all activities requiring permits from agencies of the Commonwealth. One permit application to which the MEPA process does not apply is the application for a Determination of Need (DON) for Site Assignment provided for in 310 CMR 16.05.

The MEPA regulations contain certain threshold levels related to the size of various types of projects. If the project is below the threshold level, the project does not have to go through the MEPA review process. The MEPA review thresholds for various different types of projects can be found at 301 CMR 11.03, and specifically the review thresholds for Solid and Hazardous Waste projects can be found at 301 CMR 11.03(9).

The Solid and Hazardous Waste review threshold in part states, “New Capacity… for storage …processing … (would require an ENF or EIR) unless the Project is exempt from site assignment requirements”. The proposed project, if permitted under the DON provisions of the Solid Waste Site Assignment Regulations, would not be required to apply to MEPA for either an ENF or EIR. The project as proposed here does not trip MEPA review thresholds for air or water issues.

Air Quality Control

The proposed ATAD process will have the potential to produce emissions of air contaminants, falling into two main categories: (1) process emissions; and (2) fuel burning equipment emissions. Both categories of emissions are subject to regulation under the Massachusetts Air Pollution Control Regulations, 310 CMR 7.00. The particular requirements for each category are discussed below.

1. Process Emissions

Waste handling and treating processes like the ATAD have the potential to generate significant emissions of the air contaminants dust, odor and noise. Therefore the DEP has the authority to require that the proponent file an application for approval to construct under 310 CMR 7.02 prior to commencement of construction and operation. In order to obtain the 7.02 approval, the proponent must demonstrate that the process has been well designed to minimize the formation of the air contaminants, and that the contaminants that are generated are reduced by the application of Best Available Control Technology (BACT).

Generation of dust emissions (also called particulate matter) is minimized by keeping trucks and roadways clean and free of spilled waste, and by ensuring that any dust generated inside the building will be directed to an effective dust control device before being exhausted. The systems intended for odor control often also control dust emissions; this should also be the case for this process.

Generation of odors is minimized by the following: control of the incoming feedstock; proper management of raw materials stored indoors; effective periodic building and equipment cleaning; and proper process control. In order to capture any odors that are generated, the processing building will need to be kept under negative pressure by the exhaust ventilation system. For control (destruction) of the odors in the exhaust, the proposed biofilter should be effective if it is properly designed, constructed, operated and maintained. Department policy requires that the proponent must demonstrate that the total odor control system will be sufficient to prevent the causing of nuisance odors off the proponent's property.

Generation of noise is minimized by the following: selecting inherently low-noise motors and fans; keeping doors and windows closed; placing noise-generating equipment in locations far away from sensitive receptors; and putting noise-reducing insulation and enclosures around noise sources as necessary. As with odor, Department policy requires that the applicant demonstrate that the noise from the facility will not cause a nuisance off property.

2. Fuel Burning Equipment Emissions

This facility will require various fuel burning equipment such as dryers, boilers, space heaters, etc. The 310 CMR 7.02 establishes size cutoffs for fuel utilization facilities; if the rated heat inputs of the equipment exceeds the size cutoffs, then the proponent will be required to file plans and obtain approval for the equipment under this regulation. In general the fuel utilization facilities must meet all applicable standards for emissions of criteria air pollutants (particulate matter, carbon monoxide, sulfur dioxide, and nitrogen oxides). It is anticipated that the types of fuel burning equipment ancillary to the ATAD process will be able to meet all applicable standards by inherently low-emission combustion design and by the burning of clean fuels, without the need for add-on exhaust treatment systems.

Water Pollution Control

The disposal of wastewater in the Commonwealth is regulated under the provisions of the State Clean Waters Act (MGL, Chapter 21, Sections 26-53) and regulations promulgated by the Department of Environmental Protection thereunder at 314 CMR. The wastewater from a commercial pelletizing operation would be classified by Department regulations as an industrial wastewater, and its disposal to a municipal sewer system would require a sewer connection permit from the Department pursuant to 314 CMR 7.00. The sewer connection would also be subject to local sewer ordinances and to any industrial wastewater pretreatment requirements imposed by either local requirements or by the state and federal requirements stipulated in the terms of the discharge permit issued to the municipality.

Should the fertilizer pellets produced from this operation contain any sanitary sewage or septage, the in-state disposal of these pellets would be subject to Department regulations governing land application of sludge and septage (310 CMR 32.00). As such, the pellets must first be classified by the

Department pursuant to section 32.10. Materials classified as Type I may be sold or used in the Commonwealth without further approval from the Department. The sale or use of materials classified as Type II would require prior approval from the Department. The sale or use of materials classified Type III would require individual site approval by the Department and the use of these materials recorded in the registry of deeds in the chain of title for such site.

The Clean Water Act regulations require that any leachate produced in the facility be handled and disposed of properly.

Health/Safety Issues

Safety issues associated with the use of ATAD technology in a food waste to fertilizer manufacturing facility include:

- Aerobic digestion does not produce methane gas, and therefor reduces worker exposure to risks from toxic gas and explosion.
- ATAD is recognized to be a simple and robust process, and training requirements are not identified as significant management issues.
- Spills, if they do occur, do not present a specific hazard due to temperature or caustic exposure. Chemical stocks used to adjust pH represent a source of worker risk, however, this type of risk is a standard aspect of municipal solid waste management.
- The relatively low level of staff required to operate an ATAD system, and the relatively low O & M demand of the ATAD system reduce the amount of worker hours spent at risk per ton of feedstock processed into product.
- End-product generated through the IBR ATAD process is judged to be safe, based on a comparison of time/temperature conditions achieved by the process with those required by federal regulations (40 CFR Part 257) for land-applied residuals from wastewater treatment operations. Note that the IBR ATAD process as proposed for this site will not include residuals processing; this information is presented for comparison purposes only. The regulations list acceptable treatment technologies and divide them into two categories based on the level of pathogen control they can achieve: processes to further reduce pathogens (PFRPs) and processes to significantly reduce pathogens (PSRPs). Criteria for the more stringent of these two classifications, PFRPs, is met when feedstock is "maintained for at least 30 minutes at a minimum temperature of 70C" (reference: 40 CFR 257, Appendix II; EPA/625/10-90/007, page 32). This treatment is designated as "pasteurization." Criteria for PSRPs is met by maintaining operating conditions of 55C for 4 hours were temperatures are otherwise held above 40^{o}C for 5 days. The ATAD process examined in this design review typically reports operating conditions above 70C for 50 to 60 hours, easily qualifying for the more stringent treatment classification as a PFRP technology. Paradoxically, total residence time for material treated with this technology (less than 5 days) does not comply with current criteria for the less stringent treatment classification, PSRP. In other ATAD applications, ATAD has been shown to meet "criteria for PFRP equivalency and the proposed Class A Group 1 (503) standards" for land-application uses (ibid., page 34). The IBR process additionally involves heat-treating end product at more than 100^{o}C for at least 10 minutes (with an average of 15 minutes and an upper end of 30 minutes). Finished products contain surviving thermophilic microbes such as are found in typical soil samples. Examinations conducted in this technology review have found no evidence for potential human or animal health risks or agricultural risks from thermophilic bacteria in land use applications.

LESSONS LEARNED/IMPLEMENTATION ISSUES

The case study provided in this document is based on a technology applied at a specific site. Lessons learned in both design and operations areas derived from information provided by the technology vendor and the user at that site include:

Design Issues

Due to the corrosive and abrasive nature of organic slurries, care should be taken that proper materials are used in the process; i.e., all wetted parts to be 3/16 stainless steel; all ware parts Ni-Cd. Due to the nature of deliveries of municipal and organic wastes, no down time of a plant can be tolerated. Therefore, ALL equipment has back up so that ANY piece of equipment or feed or discharge line may be shut down or disconnected while the plant will keep operating to its full capacity. This safety factor contributes to 25% of the total cost.

Maintenance of plant and capital allowance set aside for replacement should be conducted in such a manner that the plant has an indefinite life span.

Biofilter design should include provisions for expansion in the event expansions become necessary. Provisions for odor-free managing of any potential leachate from biofilter should be incorporated within the design.

Implementation Considerations

Based on experience with this technology application, lessons learned relative to future implementation of the technology are listed here. Such items may include:

<u>Labor Related:</u>

- Operating staff familiar with the mechanical trades will require no special training to operate equipment within the facility. Managing an ATAD fertilizer manufacturing facility makes use of operating skills common in water treatment operations. Bio-Dynamics has indicated to STEP that its Uxbridge facility will be managed by the Roy F. Weston, Corporation, a firm with specific strengths in areas of waste processing systems. This firm has designed, constructed, and operated treatment facilities at several sites within the Commonwealth (e.g. the 100,000-gallon per day Taunton municipal Septage Treatment Facility and the New Bedford Army Corps of Engineers wastewater treatment plant). The manager overseeing R.F. Weston's management of the Uxbridge facility is (as of this time) Mr. Greg Miller. Mr. Miller has over 25 years of experience in the wastewater field, including plant operations, management, maintenance, and regulatory interaction, and Mr. Miller has been past President of the New York Water Environment Association. His operational experience includes management roles at wastewater treatment facilities in Wilmington, DE, in Danbury, CT, in Williamsburg, VA, in Kent County, DE, and in the towns of Albany, Colonie, and Guilderland, NY. He carries a Grade 4A wastewater Treatment Operator Certification. STEP feels Mr. Miller possesses the essential skills needed to implement and oversee day to day operations of the proposed Uxbridge ATAD facility, and that Roy F. Weston Corporation has the large scale system track record sufficient to suggest that they will manage this facility appropriately.

<u>Maintenance Related:</u>

- Maintenance schedules apply specifically to pumps and mixing equipment, and should include provisions for some on-site oxyacetylene welding. Safety training with respect to handling of caustic reagents is recommended.
- Back-up systems are needed to assure continuity of fluid flow. Spare aerators and mixers are needed to assure continuity of processing operations. Bio-Dynamics has assured STEP that their operations plan includes pre-negotiated agreements with two (2) regional composting entities to accept large volumes of

partially digested product on short notice in the event of any potential catastrophic failure of their manufacturing facility. Through contract with haulers, Biol-Dynamics additionally assures STEP that they will retain sufficient provisions to collect and transfer partially digested product in a timely fashion should such action be required.

Implementation Related:

- No seasonal disruptions in operation are expected.
- Facilities can receive incoming feedstock at hours of the days that accommodate hauler and citizen schedules (rush hour traffic shipments can be avoided)
- Operations can be conducted in a batch or a semi-continuous mode by mixing incoming feedstock into digesters containing a fraction of processed slurry. Residence time varies such that a processing endpoint is reached. This processing endpoint consists of an inflection in the heat production kinetics of the microbial mass, and signals a shift in the type of nutrient being consumed within the reactor.
- No specific provisions have been reported for disposal of replaced equipment.
- The management team has 6 years of operating experience with the ATAD technology, the facility design, and supply chain management. The management team has contributed significant innovation (as indexed by patents awarded to the management team) for equipment and processes related to manufacturing fertilizer from waste food products.
- The management team has secured letters of intent from regional haulers planning to serve the Uxbridge facility, and have established themselves as credible contractors throughout the state.

Product Related:

- Bio-Dynamics has indicated to STEP their intentions to work with soil and agriculture staff of the University of Massachusetts System in study programs to assess and to confirm features of merit in their manufactured product. This intention is interpreted by STEP to represent a deep and sincere commitment by Bio-Dynamics to be a collaborative participant in agricultural practice improvement in the Commonwealth.

Management Related:

- The BioDynamics limited liability corporation will be chaired by Mr. James M. Coull, of Concord, MA who, as a general manager, will oversee contracts with facility management and collection system management organizations. Mr. Coull has 36 years of design/build experience, and is the chairman of the board of a design/build construction company that specializes in food processing and other process industries. His firm's projects include a major facility for processing shrimp in Ayre, MA. Mr. Coull currently sits as Vice Chairman for the Massachusetts Port Authority (MASSPort) with statutory responsibility for safeguarding environmental and construction interests overseen by that organization.

Benefits Derived From Application

This section will present a list of issues that were identified by the technology user as benefits as a result of installation and implementation of this technology.

Household gardeners and organic agricultural operations are receptive to low cost, high quality, carbon-rich soil amendments. Compost is promoted by the EPA as an environmentally preferred fertilizer (reducing the need both for herbicides and insecticides), and a growing health conscious public continues to expand demand for "safe" lawn and garden products and for foods and herbs produced on organic farms. Markets for food scrap compost can reasonably be expected to expand.

Food processing facilities (i.e. restaurants) are receptive to systems that will improve the efficiency, and reduce the cost, of managing food scrap waste. Due to consolidation in the waste hauling industry, haulers have increasing power to insist that waste generators comply with some segregation of waste types at their source. Quality Control over the composition of food stream wastes can be reasonably assured through cooperation of haulers.

Limitations in Application

This section will present key issues that were identified by the manufacturer as limitations to the user as a result of installation and implementation of this technology.

The Capital and Operating costs (including the feedstock supply management costs) of an ATAD fertilizer manufacturing facility may not compete favorable in locations where vermin and odor control is not a significant social factor, where conventional composting sites are available at low cost, and where easily accessed supply generators and end product markets are not seeking fertilizer with high-end user features. These conditions may apply to selected rural sites in highly agricultural districts.

PUBLISHED REFERENCES

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3. Environmental Regulations and Technology: Autothermal Thermophilic Aerobic digestion of Municipal Wastewater Sludge. US EPA Risk Reduction Engineering Laboratory (RREL) and Center for Environmental Research Information (CERI), Cincinnati, OH. September 1990. 65 pages. EPA/625/10-90/007

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APPENDIX A. LETTER OF ASSERTION FROM TECHNOLOGY PROPONENTS

BIO-DYNAMICS, LLC
48 JUNCTION SQUARE DRIVE
CONCORD, MA 01742
(978) 371-0700 FAX (978) 371-1826

May 16, 2000

Dr. Thomas R. Flanagan
STEP Technology Analyst
Environmental Technology and Business Center
Massachusetts Strategic Envirotechnology Partnership
University of Massachusetts, Boston
100 Morrissey Boulevard
Boston, MA 02125-3393

Dear Dr. Flanagan:

On behalf of Bio-Dynamics, LLC I confirm that we have critically read and understand the content of your analysis, and hereby assert that to the best of my knowledge and to the knowledge of my partners in this venture, the design and performance data contributed with reference to International Bio-Recovery Corporation's Vancouver-based manufacturing facility and our proposed plans for a fertilizer manufacturing facility in the Town of Uxbridge, Massachusetts is accurate and complete. We have no additional salient content to contribute to the issues raised in your analysis

Sincerely,
Bio-Dynamics, LLC

James M. Coull
President