A Case for Aerobic Bioreactor Landfills

SALT Inc.

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SALT Inc. *(Sustainable Aerobic Landfill Technologies) provides solutions to remedy landfill environmental issues and extend the productive life of landfill sites.*

Mission Statement

To provide complete landfill remediation, sustainability and greenhouse gas mitigation at the lowest cost while providing significant environmental, social and economic benefits.

Types of Landfills

Anaerobic: A landfill deprived of oxygen having odour, leachate and methane gas issues. Such sites require on-going perpetual maintenance. The vast majority of landfills worldwide are anaerobic.

Aerobic: A landfill in which organics are rapidly decomposed as a result of the presence of oxygen and moisture. Odour, leachate and methane emissions are mitigated. Such sites can be recycled as landfills or put to higher use.

Anaerobic Landfill Issues

Traditional landfill operations are anaerobic (no oxygen) and create short and long-term environmental risks to the air, water and land. Anaerobic sites release methane into the atmosphere helping to fuel Climate Change by contributing to Global Warming. Air quality is fouled by the intense odours associated with this type of landfill practice.

Leachate, a liquid that percolates through an anaerobic landfill and is sometimes toxic, will, over time, penetrate the layers (clay liners, layers of aggregate and geo-textile liners) designed to contain it. The leachate will ultimately enter and contaminate the ground water.

Organic matter may take up to 100 years or more to fully decompose and stabilize. The non-organic elements such as plastic, glass and rubber will remain intact indefinitely. When a landfill is closed, the surface is unsuitable for most uses other than passive recreational. The site will also require continuous monitoring, leachate maintenance and removal as required.

Conventional Solutions for Anaerobic Landfill Waste

Venting:

This is a “Do Nothing” option, which is the state of the vast majority of landfills. Vent stacks are set into sites and methane gas emissions are released directly into the atmosphere. According to the United Nations, landfill methane constitutes about 15% of all greenhouse gas emissions worldwide.

Landfill Gas Capture and Flaring (LFG):

This technology captures and incinerates landfill gases. Methane is converted into heat and carbon dioxide. Studies have shown that this process mitigates less than 40% of the methane on a site. LFG is expensive to setup and operate and the site must be monitored for the life. The remaining methane is vented. Typically, LFG is shut down within 15 years because methane production has dropped significantly. Environmental issues are still present.

Landfill Gas to Energy:

Under certain conditions, an LFG system can be considered for electrical power generation. The landfill must be very large, and still be operating as a landfill. Fresh waste adds considerably to gas generation and extends the life of the project. Gases must be analyzed for quantity, quality, moisture level, filtration cost and BTU value. The length of time gases will be generated, proximity to the grid, cost of delivery and the market value of the power are other factors that must be considered. Capital and operating costs are exceptionally high and these sites often show negative returns (see **Appendix VII**), This technology, as well, does not deal with other environmental issues.

The Anaerobic to Aerobic Solution

The aerobic process is a natural solution and is the most efficient way of mitigating risks and maximizing cost benefits. An aerobic bioreactor can operate on either new or existing landfills (**Appendix 1**).

Setup & Operation

On a new site, the landfill would be constructed with a series of traditional but "state of the art" cells that incorporate the latest technology of landfill liners and leachate collection systems. Each "cell" is designed to accommodate one year of material receipts.

Material is received, placed into the cell, and heavily compacted. Daily cover material is placed on the site, to discourage pests, similar to traditional anaerobic landfill sites. After the cell is filled, a series of vertical wells are drilled into the surface with dispersion points approximately every 10 feet on the vertical, (for the distribution of both air and moisture). Low-pressure compressors are used to pump air into the waste mass. Leachate, recovered through the traditional collection system, is injected into the waste. Sensors monitor the landfill and record the various gases and temperatures. The resultant data is interpreted and used to optimize the process by controlling the flow rates of air and moisture into each well. Sensor monitoring can be done remotely.

The vertical air and water shafts consist of perforated plastic pipes that extend to the bottom of the waste mass. These wells are interconnected on the surface by flexible plastic pipe through which compressed air is supplied. Leachate and rainwater runoff can be added to the air when it is forced into the shafts. Carbon dioxide and water vapour are released to the atmosphere through vent pipes set at strategic locations between vertical airshafts. (It should be noted that the system works better at cooler temperatures. Winter conditions in Canada are well suited for the application.)

Dramatic changes occur almost immediately. Within a few weeks the methane-producing anaerobic bacteria quickly perish and are replaced by aerobic bacteria that break down the organic matter 30 to 60 times faster. Methane gas production ceases and the only emissions are non-toxic carbon dioxide and water vapour. According to the UN, methane (CH4) is 21 times more harmful to air quality than carbon dioxide (CO2). A sign of the positive air quality changes will be rapid growth of plant life on the site.

Odours are virtually eliminated. The aerobic degeneration of organic matter is considered "natural" by the United Nations Clean Development Mechanism (CDM) Board and follows UN guidelines for emission reductions. The process is similar to the decomposition of leaves on the forest floor or kitchen waste in the backyard composter. When exposed to oxygen and water, organics are naturally decomposed in about three years and emit very little odour.

Leachate is re-circulated back into the landfill, preventing it from compromising the groundwater. In addition, the aerobic bacteria improve the quality of the leachate, making it considerably less toxic. Studies have shown that the biological oxygen demand (BOD) decreases from 100,000 to about 10 mg/litre. The optimum operating temperature for the process is 55 degrees C. Since the system operates similar to a "compost" operation, heat is generated and dissipates the leachate as water vapour. This minimizes the chance of leachate incursion into the groundwater. Leachate is also "cleaned", contains less organic material and emits fewer odours. As well, the volume of leachate will shrink to the point that outside water maybe required for the aerobic process to continue (waste water sludge can be substituted). Landfills that have a compromised lining can be taken out of service allowing the area groundwater to be decontaminated.

When decomposition is complete, the waste mass can be mined and classified. The waste cell is typically composed of 50% organics, 5% to 7% metals and 30% inerts (plastics and other non-biodegradables). The process is approximately 95% efficient, dependant on the composition of the waste. The site will NOT revert to an anaerobic state.

Including analysis, engineering and operation, an existing anaerobic site can be retrofitted to be aerobic in a matter of months. The cost of this conversion is approximately $6.00 per ton of waste in place. Economies of scale have a direct bearing on this cost.

Material Separation

Using mature open pit mining and classification, waste can separated into:

1. Compost 50%
2. Metals 5%
3. Commingled Plastics 12%
4. Carpet 7%
5. Glass 3%
6. Ceramics 2%
7. Rubber 6%

These percentages are based on older non-bluebox sites where tires were accepted. Local collection practices will affect the composition.

Other materials (both hazardous and non-hazardous) may be found in a site such as: batteries, paint cans, chemical drums, cars, tree stumps and construction materials. Mining of the site will allow these items to be dealt with in a responsible manner (either removed, recycled or taken to a hazardous waste facility). Through classification, about 55% of the mass can be separated and recycled directly (compost & metals).

Value-Added Products

In conjunction with the National Research Council of Canada, SALT has developed a process to manufacture "value-added" products from the inert materials such as plastic, carpet, rubber, glass and ceramic that remain after classification. Products such as railway ties, utility poles, landscaping blocks, marine components and pallets can be created. The products are impervious to weather conditions, non-toxic and cost-effective.

The cost to implement this mining and recovery process will range from $12 to $25 per ton. The cost is dependant on the desired speed of recovery and the size of equipment used in the process.

After the usable material is processed into value-added products, about 15% of the total waste mass remains. This unusable material can be taken to a more appropriate site such as a hazardous waste facility or retained for future recycling activities.

At the end of approximately four years, the waste has been recycled, made into products, or been consigned to a more appropriate waste disposal area. This compares favorably with a typical anaerobic landfill site, where all of the waste remains in place forever.

Site Reclamation

Once the process is complete, the site can be reconditioned. In a typical landfill, safety features break down over time, and eventually the environment is compromised. With the aerobic process, a cell can be emptied and liners and leachate systems can be examined and re-conditioned. New landfill approvals are not necessary (a long and costly exercise). Instead, existing sites can be used as "recycling" centres. Sound management practices can be used to protect the environment.

The aerobic bioreactor process is **NOT A LANDFILL** process, but rather a long-term, sustainable recycling solution, designed to emulate the forces of nature, and mitigate against harmful effects to the environment. It is an exceptionally cost-effective and socially responsible solution to the handling of municipal solid waste.

Equipment and Procedures

The equipment required is readily available in portable or stationary configuration. Large low-cost moveable fabric-covered structures are available to enclose the operation for protection from the weather and contain dust, noise etc.

1. Piping supplies are common drainage materials available at building supply outlets.
2. Air and water supply pumps are available at industrial equipment supply outlets.
3. Mechanical separators, sorters and shredders are available from a number of suppliers in many sizes and capacities.
4. Crushing services for concrete, asphalt, and aggregates are available in most communities. Material could be stored until sufficient volume warrants bringing in a mobile crusher or the material could be sold to a gravel operation for crushing offsite. (This is a common service at most gravel pit operations.)
5. Shredding services for lumber, pallets, building materials, trees and other items are available in larger communities to which materials could be sold.
6. Metals can be sold to salvage yards, classified and sold to smelters.
7. The process generates large volumes of compost. Some may be sold for landscaping use. In many areas having land of marginal agricultural value, the application of compost would enhance the growing of certain crops. Areas with marginal forest cover could be improved with compost to become economical wood or pulp producing land.
8. The processing of the residual plastic and other inert non-salvaged materials can be done either on-site or off-site.

Aerobic Process Advantages

1. Operational or closed landfills can be used as permanent community recycling facilities.
2. Closed landfills can be recycled and the land recovered for higher value uses.
3. Communities will be able to accommodate their own waste without costly transfers to remote locations with resulting traffic and associated pollution.
4. New landfills are not required. Existing sites can be recycled, eliminating the need for new infrastructure such as roads, sewers and utilities.
5. Landfill size can be substantially reduced. Space to accommodate 5 to 6 years of waste would only be necessary as opposed to traditional landfills designed to hold at least 20 years of waste before requiring closure and perpetual maintenance.
6. Groundwater contamination is mitigated.
7. Existing contaminated groundwater can be remediated.
8. Leachate is contained and ultimately eliminated prior to any seepage.
9. Odours, a major NIMBY (not in my back yard) issue, are mitigated.
10. Safety systems can be examined and repaired when the landfill cells are reconditioned (after the mining process), thus providing reassurance to nearby residents that health and safety issues are properly handled and that their quality of life is not compromised.
11. Valuable economic resources, originally landfilled, can be recovered, minimizing the requirement for virgin materials.
12. Air quality issues are eliminated. The United Nations calculates that about 15% of anthropogenic greenhouse gases are generated from landfills.
13. The total cost of the aerobic process is approximately $5 per ton of material in the landfill. Mining and recovery costs range from $12 to $25 per ton. Compared with landfill tipping fees the process is economically viable and physically realistic.

14. Compost extracted from a processed site could be used in a variety of ways - landfill cover, municipal use, community group use, personal use, agricultural use for non-food crops, construction use, and clean fill to name a few. Costs will vary by site and usage.
15. Alternatives such as incineration require massive capital and operating costs. State of the art incineration facilities with annual capacities of 500,000 tons are estimated to exceed $300 million in capital costs. To process MSW (municipal solid waste), construction and demolition waste as well as commercial waste, the city of Toronto would require at least 5 to 7 such facilities. In addition, operating costs, even after any power grid gains, would be in the range of $150 per ton, almost 3 times the cost of landfllling. (**Appendix VII** - reports on the city of Detroit, Michigan incineration facility.)
16. Green Box programs could be eliminated. Organic waste would be composted through the aerobic bioreactor and recovered through the mining and classification process. As well, the costs of separate collection and composting facilities would be unnecessary.
17. Blue Box program materials could be assigned to the "recycling facility" and incorporated directly into the manufacture of "value-added" products.
18. Since the process is more environmentally friendly than any alternative, (especially incineration), environmental groups readily embrace the technology.
19. Landfills footprints can be minimized through recycling and reuse. Developers would embrace the process for conserving land for alternative use.
20. Closed landfills with environmental issues could be reconditioned at minimal cost.
21. Existing sites can be recovered for higher value usage.
22. Wastewater sludge could be processed through the bioreactor reducing the impact on overburdened municipal wastewater treatment facilities.
23. Pre-sorting of material prior to landfilling is possible, however, it is manually intensive, very costly and extremely hazardous for the workers (chemicals, needles, broken glass, propane tanks and other hazards exist).

Recycling

Any successful recycling project must create products that have value and an available market.

1. Compost will be the major component. In some jurisdictions, it is graded and approved for specific uses. Ontario has very stringent regulations for compost. The use of compost for commercially grown crops for human consumption will have to be investigated.
2. Recycled concrete, asphalt and crushed stone have a ready market.
3. Wood chips have a ready market for a variety of uses: bedding for horses and other livestock, paper and particleboard production, and landscaping applications.
4. Metals have a well developed market
5. Clear glass & coloured glass containers have been problematic in recycling but can be incorporated into value-added manufactured products.

6. Paper, cardboard and other organic elements that pass through the initial aerobic process can be shredded and incorporated into the value-added products that are manufactured.
7. Waste plastic, carpet, rubber and similar products have been a major challenge to recyclers. Through the use of a secondary technology, these non-salvageable items can be formed into value-added products. With the inclusion of steel reinforcement, products such as utility poles, fence posts, railroad ties, and wharf and marine components can be produced. The material has many of the attributes of concrete or wood but does not absorb water (no freezing/thawing issues, or salt degradation) and is not affected by algae or other marine life. Depending on its' composition, it can be nailed and cut to size.

Carbon Credits

With the advent of global warming and climate change, conventional wisdom advocates penalties for excessive production of methane, the most common and harmful of the greenhouse gases. The majority of carbon offset programs worldwide are "cap & trade" systems whereby polluters such as coal-fired electrical generators are given annual emission thresholds they must strive to meet. If annual methane emissions fall under the threshold then credits are issued. If thresholds are exceeded, then penalties are imposed. Polluters must pay the penalties or purchase credits from firms or projects (such as aerobic landfill projects) that have credits available. Penalties typically increase year over year and supply and demand dictates the price of the credits. Carbon exchanges have evolved for the trading of credits. "Cap & trade" systems provide the best incentive to encourage polluters to get their houses in order.

Typically, every tonne of landfill waste generates about 1.4 tonnes of methane. The aerobic bioreactor technology reduces that output by approximately 85%. Therefore one ton of landfill waste is roughly equal to one carbon offset credit. Other methods (gas capture & flaring and LFG energy generation) fall well short of the aerobic process in terms of greenhouse gas mitigation and thus generate significantly less credits.

In Alberta, penalties for the first year of the provincial carbon reduction program have been set at $15 per ton of methane emitted above the allowable limit. The market will likely see initial carbon offsets trading in the $10 to $12 range..

Carbon offset credits provide the economic driver to fund the aerobic process. This means that a landfill owner can have a site remediated at NO COST.

Current Status in Canada

Alberta was the first province in Canada to adopt a carbon trading mechanism. Baseline Emissions of Calgary drafted and presented the aerobic landfill protocol to Alberta Environment. Baseline is the recognized leader in Canada in the field of carbon emission systems and technologies. Baseline developed the protocol standards, co-authored the Alberta trading system legislation and wrote almost all of the 25+ accepted protocols.

In December of 2007, Baseline was retained by Environment Canada to evaluate over 350 various Carbon Protocols from trading systems worldwide. Each protocol was graded on a point total of 27. The aerobic landfill process received a grade of 25.5, placing it in the top 20, and ensuring it of being a primary protocol for the Federal government.

In early February of 2008, the Province of Ontario retained Baseline to establish GHG protocols for Ontario. The deadline for completion is early April 2008. The aerobic landfill process is one of the protocols that the province will adopt. It is anticipated that Ontario will implement a carbon reduction trading system before the end of 2008.

Baseline has openly opposed the proposed Ontario mandate of gas flaring for landfills over 1.5 Million tonnes. They argue that such legislation is contrary to the public good and will inhibit the normal development of a GHG trading system. It is suspected that the proposed legislation will NOT go forward.

The aerobic bioreactor is considered to be the most effective carbon mitigation technology in Canada. It produces more carbon reductions, faster and at less cost than any other technology.

Why is this important? Because efficient carbon reduction not only mitigates more greenhouse gases, but also becomes the economic driver to offset the cost of implementing the aerobic technology.

By employing an aerobic bioreactor, the value of the generated credits would offset the cost of implementing and operating the system. In essence, the system would be **cost-free.**

Conclusion

The aerobic bioreactor and related ancillary technologies provide a cost-effective, environmentally friendly, sustainable solution to the problems associated with waste collection, recycling, water quality, climate change and quality of life.

Many capital-intensive operations associated with waste collection and disposal (municipal waste, municipal sludge, blue box program, green box program) can be combined into one low-cost solution for the greater good.

Environmental issues such as greenhouse gas emissions, odours, and water and soil contamination, can be mitigated. Land use can be optimized through the reclamation of both operating and closed landfills.

Appendix I

Aerobic Bioreactor

Traditional Anaerobic Landfill

Traditional landfills are anaerobic. Waste material is compacted and covered daily with material to discourage pests as well as to control odours. Once a cell is filled, it is "capped", generally with an impervious layer of clay that prevents air and moisture from entering the landfill mass. Anaerobic bacteria thrive and slowly decompose the organic matter. Under these conditions, it could take well over a hundred years to decompose the organics. Methane gas and pungent odours (both byproducts of anaerobic decomposition) are generated and slowly escapes through the clay cap designed to contain them. The land is generally unstable and not suitable for any use other than surface leisure activities such as golf courses.

Most anaerobic landfills require perpetual monitoring and maintenance. Gases and leachate need to be dealt with as required. Sites will slump and need to be leveled to control weeds and grass. Installation of vents may also be necessary. These post-closure costs are borne by the landill owner and typically passed on to the customer (taxpayer).

Incorporating an Aerobic Bioreactor

An anaerobic landfill is analyzed to determine the compaction rate of the site (the amount of waste in weight per yard), the composition of the waste, the amount of leachate and flow rates, as well as gas predictions. Once the analysis has been done, an aerobic bioreactor system can be designed.

A series of "wells" are drilled into the surface of the landfill in a grid pattern. Individual pipes are used at each wellhead for each 10 feet of depth into the landfill. If the waste mass is 40 feet deep, then pipes will be inserted to the 10, 20 and 30-foot levels. Low-cost ABS plastic pipe is used to circulate moisture (leachate is preferred) into the landfill. Air is also injected into the waste through another set of wells using low-pressure compressors and inexpensive "Big O" drainage pipe.

When air is pumped in, the anaerobic bacteria quickly perish and are rapidly replaced by aerobic bacteria. The transformation from anaerobic to aerobic typically occurs within 2 to 3 weeks.

Aerobic bacteria aggressively decompose the organic matter. Carbon in the waste combines with oxygen in the air to produce carbon dioxide and heat. Methane production ceases. Odours virtually disappear. A typical aerobic landfill is "composted" within 24 to 36 months. Aerobic decomposition is 30 to 60 times faster than the anaerobic process.

There are several additional advantages beyond the rapid stabilization of the landfill.

1. Leachate that percolates through the landfill is re-circulated back into the site, minimizing the opportunity for it to breach the protective systems designed to contain it.
2. Leachate contains dissolved organics, which are also processed by the aerobic bacteria, which significantly improves leachate quality, particularly the Biological Oxygen Demand (BOD) levels.
3. Because the process generates substantial heat, much of the leachate is vented into the atmosphere in the form of water vapour. This effectively reduces the quantity of leachate and minimizes the possibility of a safety system failure.
4. When the aerobic process is finished, the landfill is stabilized, the organic matter is composted and the site “slumps”. This settling action can recapture up to 25% of the original airspace.
5. Post-closure maintenance costs are significantly reduced.

Appendix II

Some Existing Aerobic Landfill Projects

USA

- Williamson County, Tennessee
- Black Warrior Landfill, Coker, Alabama
- Private Landfill, Atlanta, Georgia
- Aiken County, South Carolina
- Three Rivers Landfill, South Carolina
- Cumberland County, New Jersey
- USDOE – Savanna River Site, South Carolina
- University of South Carolina
- University of Georgia, Athens, Georgia
- Arizona State, Tucson, Arizona
- Yolo County, California
- University of South Florida, Tampa, Florida
- Several sites – New York State

Europe

- University of Hamburg, Hamburg, Germany
- University of Basque Country, Spain
- OSE (Open Software Enterprise Entwicklungs), Austria

Middle East

- Tel Aviv, Israel
- American University of Beirut, Lebanon

Japan

- University of Fukoka, Fukoka

Some Aerobic Sites in Process

India

- Bhalswa Landfill, Delhi
- Ghazipur Landfill, Delhi
- Ghandipur Landfill, Hyderabad

Israel

- Abu Dis Landfill, S.E. Israel
- Haifa

Jordan

- Two sites

Appendix III

Associated Aerobic Experts

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Appendix IV

The Kyoto Accord*

The Kyoto Accord is a formal international agreement between 158 nations wherein each country has negotiated and been assigned certain green house gas emission targets that they must reach by specific dates. The agreement came into force in February 2005 and is administered by the United Nations. Countries that do not achieve their targets will pay a heavy price. In future compliance periods, they will bear a penalty of 30% more reductions. Canada is a signatory to the agreement but, as of this writing, has not set targets for reductions.

Under the agreement, the costs of compliance will be very high, particularly in developed nations that generate a majority of offending emissions. The agreement makes provision for a “trade and cap” system for the trading of emission credits. In order to minimize the total cost of reducing green house gas emissions, countries and companies can purchase credits from sources that have excess credits. Projects that generate emission reductions at the lowest cost will proceed and can sell their credits to countries and companies that cannot economically justify limiting their emissions because of the high cost of doing so. These credits, when sold, will provide the capital required to bring projects to market.

The market for greenhouse gases (GHG) is flourishing in Europe. Initial trading volumes were small, but have escalated to daily trading volumes of millions of credits and are expected to increase exponentially in the next several years.

Existing Conditions

When the United Nations examined the generation of GHG, there were several areas of activity that comprised a significant percentage of the emissions: fossil fuel electrical power generation, vehicles, chemical industry, oil & gas companies, metals & mining industries and landfills. The United Nations concluded that about 15% of all emissions are generated by landfills, primarily in the form of methane and carbon dioxide. Methane is over 21 times more harmful to the atmosphere than carbon dioxide. On average, worldwide, every person on the planet generates about one ton of waste annually and landfills generate about one ton of carbon equivalent for every ton of material in placement. By eliminating methane, large-scale reductions of GHG emissions can be achieved.

Existing and alternative emission reduction technologies are very expensive. Coal-fired electrical generation facilities will require expensive scrubbers and ultimately be replaced by “clean air” technologies such as natural gas burning facilities, wind power or nuclear reactors. Automobile emissions will be replaced by hydrogen fuel cells and electrical “hybrids”. Metal and mining companies will have to employ scrubbers and high temperature gas incinerators. All of these technologies have a high cost of implementation and operation as well as significant technological risks. Hydrogen fuel cell development, for example, is expensive and requires the development of new fueling technologies to implement.

The conclusion of virtually every authority regarding gas emissions reduction has been that the easiest, most cost-effective process, is to mitigate GHG emissions from landfills. Landfills are universal and generate large volumes of GHG. The technology to control landfill gases is mature and has the least risk.

United Nations Position on Aerobic Processes

Landfills are engineered to prevent moisture and oxygen from entering the waste mass and creating toxic "leachate" which will affect groundwater. Typically, landfills are "capped" with a thick layer of high-density clay to prevent incursions, thus allowing anaerobic bacteria to flourish. The anaerobic bacteria slowly decompose the organic elements and produce methane and carbon dioxide gases.

The United Nations, under the Kyoto Accord, has stated that aerobic processes are **NATURAL** processes. In the autumn, leaves fall onto the forest floor, are exposed to moisture through rain and snow and are "composted" naturally in about 3 years. Aerobic bacteria flourish and combine the carbon elements of the organic material (leaves) with the oxygen from the air producing carbon dioxide. There is no methane production and there is very little odour, if any.

The UN has further stated that since the aerobic process is natural, any carbon dioxide generated will not be netted against methane elimination. This means that any aerobic process that eliminates methane will enjoy the full affects of that methane reduction without any net reduction in credits for carbon dioxide production.

Various Kyoto Protocol GHG Commodities

Assigned Amount (AAU) is the total amount of greenhouse gas that each ratifying country is allowed to emit during the first commitment period (2008 – 2012) of the Kyoto Protocol. AAU's are issued by governments that have emission reduction commitments. They can be traded between countries pursuant to international emissions trading, provided that these countries are fully compliant with eligibility requirements.

Certified Emission Reductions (CER) are units of greenhouse gas reductions generated from CDM projects (in countries that do not have emission reduction commitments under the Kyoto Protocol), verified by external, UN-accredited third party verifiers, and issued by the regulatory body of CDM, the CDM Executive Board. CER's can be used for compliance with Kyoto Protocol obligations or to meet emissions caps under the European Union Emissions Trading Scheme. CER's are often traded in forward contracts.

Emission Reduction Units (ERU) are units of greenhouse gas reductions generated from Joint Implementation projects (in countries, i.e. typically, economies in transition, that have emission reduction commitments under the Kyoto Protocol), verified by external UN accredited third party verifiers (under what is known as track 2, JI), and issued by the host country. ERU's are also often traded in forward contracts.

Kyoto commodities are measured in tonnes of CO_2 equivalent. All Kyoto commodities have a compliance value until 2012.

* Additional information on the Kyoto Accord and Climate Change:

United Nations:
http://unfccc.int/kyoto_protocol/items/2830.php

Simplified Answers on Kyoto and GHGs:
http://www.answers.com/topic/kyoto-protocol

Climate Change Central – informative Canadian site:
http://www.climatechangecentral.com/default.asp?V_DOC_ID=835

Appendix V

Projected Ontario Waste Aerobic Emission Reductions Table

Projected Aerobic Emission Reductions For Ontario Waste (1996 to 2006) *

Year	Population of Ontario	Waste Disposal (Tonnes)	Aerobic Emissions Reduction (Tonnes-CO2)
1996	10,753,573	8,913,786	8,227,405
1997	10,740,868	6,659,338	7,924,612
1998	10,908,163	6,988,157	8,315,907
1999	11,075,458	6,778,180	8,066,035
2000	11,242,753	7,615,923	9,062,948
2001	11,410,045	7,416,529	8,825,670
2002	11,913,397	7,743,708	9,215,013
2003	11,963,749	7,776,437	9,253,960
2004	12,416,749	8,070,887	9,604,355
2005	12,558,669	8,163,135	9,714,130
2006	12,686,952	8,246,519	9,813,357
	Total Emission Reductions:		**98,023,392**

* Based on US EPA Standard "Landgem" Gas Prediction Model calculations

Appendix VI

Statistics Canada Population and Waste Tables

1. **Population of Ontario - 1851 to 2001**

2. **Population of Canada and Provinces by Age Group – 2006**

3. **Waste Disposal by Source, By Province – 2000 and 2002**

Statistics Canada Statistique Canada Canadä

Related tables: Vital statistics.

Population urban and rural, by province and territory
(Ontario)

	Total population	Urban	Rural	Urban	Rural
	number			% of total population	
Ont.					
1851	952,004	133,463	818,541	14	86
1861	1,396,091	258,192	1,137,899	18	82
1871	1,620,851	355,997	1,264,854	22	78
1881	1,926,922	575,848	1,351,074	30	70
1891	2,114,321	818,998	1,295,323	39	61
1901	2,182,947	935,978	1,246,969	43	57
1911	2,527,292	1,328,489	1,198,803	53	47
1921	2,933,662	1,706,632	1,227,030	58	42
1931	3,431,683	2,095,992	1,335,691	61	39
1941	3,787,655	2,338,633	1,449,022	62	38
1951	4,597,542	3,251,099	1,346,443	71	29
1956	5,404,933	4,102,919	1,302,014	76	24
1961	6,236,092	4,823,529	1,412,563	77	23
1966	6,960,870	5,593,440	1,367,430	80	20
1971	7,703,105	6,343,630	1,359,480	82	18
1976	8,264,465	6,708,520	1,555,945	81	19
1981	8,625,107	7,047,032	1,578,075	82	18
1986	9,101,695	7,469,420	1,632,275	82	18
1991	10,084,885	8,253,842	1,831,043	82	18
1996	10,753,573	8,958,741	1,794,832	83	17
2001	11,410,046	9,662,547	1,747,499	85	15

Note: The rural population for 1981 to 2001 refers to persons living outside centres with a population of 1,000 AND outside areas with 400 persons per square kilometre. Previous to 1981, the definitions differed slightly but consistently referred to populations outside centres of 1,000 population.
Source: Statistics Canada, Censuses of Population, 1851 - 2001.
Last modified: 2005-09-01.

To find more information related to this table, consult Definitions, data sources, and methods.

Date modified: 2005-09-01

Related tables: Population characteristics.

Population by sex and age group, by province and territory
(Number, both sexes)

	2006			
	All ages	0 to 14	15 to 64	65 and older
	Both sexes (thousands)			
Canada	**32,623.5**	**5,644.6**	**22,664.6**	**4,314.2**
Newfoundland and Labrador	509.7	78.3	362.4	69.0
Prince Edward Island	138.5	24.0	94.6	19.9
Nova Scotia	934.4	147.7	650.7	136.0
New Brunswick	749.2	118.2	524.4	106.6
Quebec	7,651.5	1,241.6	5,334.5	1,075.3
Ontario	12,687.0	2,262.9	8,782.6	1,641.5
Manitoba	1,177.8	228.0	790.0	159.8
Saskatchewan	985.4	190.0	648.3	147.0
Alberta	3,375.8	637.4	2,386.0	352.3
British Columbia	4,310.5	690.2	3,018.7	601.5
Yukon Territory	31.2	5.6	23.3	2.3
Northwest Territories	41.9	10.2	29.7	2.0
Nunavut	30.8	10.4	19.5	0.9

Note: Population on July 1.
Source: Statistics Canada, CANSIM, table (for fee) 051-0001.
Last modified: 2006-10-26.

Find information related to this table (CANSIM table(s); Definitions, data sources and methods; *The Daily*; publications; and related Canadian Statistics tables).

Date modified: 2006-10-26

Statistics Canada Statistique Canada — Canada

Related tables: Waste management.

Waste disposal, by source, by province
(Newfoundland and Labrador, Prince Edward Island, Nova Scotia)

	2000	2002
	tonnes	
Canada		
Total waste disposed	**23,168,870**	**23,835,731**
Residential sources	9,069,170	9,455,204
Industrial, commercial and institutional sources	11,203,613	11,563,999
Construction and demolition sources	2,896,087	2,816,528
N.L.		
Total waste disposed	**398,818**	**376,593**
Residential sources	x	216,218
Industrial, commercial and institutional sources	146,843	140,377
Construction and demolition sources	x	19,999
P.E.I.		
Total waste disposed	**x**	**x**
Residential sources	x	x
Industrial, commercial and institutional sources	x	x
Construction and demolition sources	x	x
N.S.		
Total waste disposed	**391,827**	**389,194**
Residential sources	171,627	169,649
Industrial, commercial and institutional sources	x	176,625
Construction and demolition sources	x	42,921

x : suppressed to meet the confidentiality requirements of the Statistics Act

Note: Total waste disposed is the total amount of non-hazardous waste disposed of in public and private waste disposal facilities. It does not include waste disposed of in hazardous waste disposal facilities nor waste managed by the waste generator on site. Sources of non-hazardous waste disposed of are derived from reported sources of non-hazardous waste collected and transported for disposal.

Source: Statistics Canada, Environment Accounts and Statistics Division, Catalogue no. 16F0023X.

Last modified: 2006-07-14.

To find more information related to this table, consult Definitions, data sources, and methods, 2009 and 1736.

Date modified: 2006-07-14

Related tables: Waste management.

Waste disposal, by source, by province
(New Brunswick, Quebec, Ontario, Manitoba)

	2000	2002
	tonnes	
N.B.		
Total waste disposed	**415,058**	**413,606**
Residential sources	198,603	203,506
Industrial, commercial and institutional sources	x	154,812
Construction and demolition sources	x	55,288
Que.[1]		
Total waste disposed	**5,806,200**	**5,543,800**
Residential sources	2,679,000	2,876,000
Industrial, commercial and institutional sources	2,655,000	2,261,000
Construction and demolition sources	472,200	406,800
Ont.		
Total waste disposed	**8,931,601**	**9,645,633**
Residential sources	3,318,478	3,438,408
Industrial, commercial and institutional sources	4,606,409	5,193,240
Construction and demolition sources	1,006,714	1,013,985
Man.		
Total waste disposed	**914,511**	**896,556**
Residential sources	451,505	412,612
Industrial, commercial and institutional sources	x	405,954
Construction and demolition sources	x	77,990

x : suppressed to meet the confidentiality requirements of the Statistics Act

Note: Total waste disposed is the total amount of non-hazardous waste disposed of in public and private waste disposal facilities. It does not include waste disposed of in hazardous waste disposal facilities nor waste managed by the waste generator on site. Sources of non-hazardous waste disposed of are derived from reported sources of non-hazardous waste collected and transported for disposal.

1. Figures are derived from the results of surveys conducted by the province.

Source: Statistics Canada, Environment Accounts and Statistics Division, Catalogue no. 16F0023X.

Last modified: 2006-07-14.

To find more information related to this table, consult Definitions, data sources, and methods, 2009 and 1736.

Date modified: 2006-07-14

Related tables: Waste management.

Waste disposal, by source, by province
(Saskatchewan, Alberta, British Columbia)

	2000	2002
	tonnes	
Sask.		
Total waste disposed	**821,964**	**795,124**
Residential sources	272,104	278,692
Industrial, commercial and institutional sources	x	441,109
Construction and demolition sources	x	75,323
Alta.		
Total waste disposed	**2,750,004**	**2,890,294**
Residential sources	824,990	866,398
Industrial, commercial and institutional sources	x	1,380,306
Construction and demolition sources	x	643,590
B.C.		
Total waste disposed	**2,581,335**	**2,744,901**
Residential sources	890,789	936,774
Industrial, commercial and institutional sources	1,264,056	1,346,669
Construction and demolition sources	426,490	461,458

x : suppressed to meet the confidentiality requirements of the Statistics Act

Note: Total waste disposed is the total amount of non-hazardous waste disposed of in public and private waste disposal facilities. It does not include waste disposed of in hazardous waste disposal facilities nor waste managed by the waste generator on site. Sources of non-hazardous waste disposed of are derived from reported sources of non-hazardous waste collected and transported for disposal.

Source: Statistics Canada, Environment Accounts and Statistics Division, Catalogue no. 16F0023X.

Last modified: 2006-07-14.

To find more information related to this table, consult Definitions, data sources, and methods, 2009 and 1736.

Date modified: 2006-07-14

Appendix VII

City of Detroit Incineration

1. **Incinerators cost Detroit Money & Clean Air**
2. **Detroit Waste Incinerator: Billion Dollar Boondoggle**
3. **For A Clean and Safe Detroit: Close the Country's Largest Incinerator**

Incinerators cost Detroit Money & Clean Air
ROB CEDAR / The Detroit News – August 28, 2002

We are hooked on incineration and it's a dirty, expensive habit.

Not only does Wayne County have two municipal waste incinerators, one of which is the largest in the country, but we also have the state's only medical waste incinerator and an old sewer sludge incinerator. Moreover, the state Department of Environmental Quality recently approved a second sewer sludge incinerator that will be the largest of its kind.

One issue is that pollution permits issued for incinerators are based on something called achievable technology. That means they must use the best methods available to minimize release of toxins -- though none of the methods eliminates harmful emissions. Instead, they only achieve 60 to 90 percent reduction.

As a result, thousands of tons -- yes, tons -- of toxic substances are legally released each year nationwide. And that's if everything is working within the permit limits.

Additionally, toxins that do not go up the stack become concentrated in the ash and filter dust. These end products are classified as hazardous or special waste that must be disposed of in special, costly landfills.

A list of the toxic chemicals released along with the potential health dangers, would take more space than is available here. But to illustrate the point, let's look at the permitted mercury emissions for the Detroit Municipal Incinerator near the intersection of I-75 and I-94.
This single facility releases enough mercury each year to contaminate all of Lake St Clair. This becomes believable when we consider that Lake St. Clair and every other inland lake in Michigan has fish advisory warnings for mercury. Incinerators also are the biggest source of dioxins, a known carcinogen often called the most toxic substance known.

Inflated costs

Incinerators are expensive to operate, with much of the cost going toward futile efforts to make them safe.

After the Detroit incinerator failed emission tests, for instance, the city was ordered to install more than $200 million in equipment upgrades. And the Central Wayne Incinerator in Dearborn Heights paid more than $100 million to expand ash handling capacity and upgrade the incinerator. After the Medical Waste Incinerator in Hamtramck failed to meet its mercury emissions limit, the owners spent more than $2 million to upgrade the pollution reduction equipment, but still failed the mercury tests.

To pay for the high startup cost and expensive upgrades, communities sending their waste to these incinerators are forced into long-term contracts and financing schemes locking them into paying higher costs than competitive landfill rates.

For example, Wayne, Westland, Garden City, Inkster and Dearborn are all locked into long-term contracts to feed the Central Wayne Incinerator.

These contracts are not without local criticism. Westland voters this month rejected for the second time a tax renewal to pay for the incinerator. In response, Mayor Sandra Cicirelli *threatened cuts in services. "The (40-year) contract is binding and the money is going to have to come from somewhere."*

The city may put the incinerator tax question back on the ballot for a third time this November. Councilwoman Cheryl Graunstadt doesn't feel Westland taxpayers should be asked to pay "a debt that never seems to end," as she put it. She added that she "could not support additional public funds for the incinerator without a comprehensive plan to phase out incineration."

Also suffering from bloated incineration costs are Detroit and the communities sending waste to the Detroit incinerator. Some are forced to pay upwards of $130 per ton, while Toronto trucks its trash to Wayne County landfills for as little as $11 a ton.

The same is true with sewer sludge. As plans move forward to build another sewer sludge processing incinerator in the already polluted southwest Detroit Delray neighborhood, Canadian sludge is being trucked to special Michigan landfills. Did you know that most of the recent water rate increases were to upgrade the sludge incinerator?

Fairness issue

Another concern is that incinerators often are in poor or minority neighborhoods. These older industrialized neighborhoods are already overwhelmed with air pollution from a number of sources and their residents suffer from elevated levels of respiratory problems, including asthma and lung diseases. Higher rates of birth defects, low birth weights and increased cancer risk also are seen.

The movement to erase such inequities is called environmental justice and is an issue of human and civil rights.

Everybody has the right to breathe clean, healthy air and cities should not be tied to long-term, bloated contracts that take valuable resources from our limited city budgets while poisoning our communities. Families should not have to trade good health for affordable housing.
If we are serious about the revitalization of our urban neighborhoods, we have to address the issues of air pollution and environmental justice. We need to understand that our reliance on incineration is bad for our health, bad for our budgets and bad for our neighborhoods.

Communities need to take a stand against incineration by finding ways to break the habit.

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Detroit Waste Incinerator: Billion-Dollar Boondoggle
The City of Detroit could have saved over $55 million in just one year if it had never built the incinerator.

(October 2005)

What could the City of Detroit do with a billion dollars? Wasteful and impractical only begin to describe how the City of Detroit, faced with a $300 million deficit for the current fiscal year, will have misspent about one billion dollars over the course of 20 years on a single project -- the Detroit Incinerator.

It's worth it to imagine a "What if?" scenario to illustrate the incredible folly that has come to plague a city in perpetual financial trouble -- currently facing hundreds of layoffs and a continuing population decline -- because it illustrates the dire need for an alternative. What if Detroit never built the incinerator and simply landfilled all of its trash instead?

In 2003, Detroit generated 575,896 tons of trash. Operation of the Detroit Incinerator is overseen by the Greater Detroit Resource Recovery Authority (GDRRA), which has a contract with City Management (a subsidiary of Waste Management) for disposal of trash at a landfill for $33.25/ton. Had Detroit landfilled its trash in 2003, the total bill would have come to a little over $19 million. The amount GDDRA charged Detroit to burn the trash? An unbelievable $75 million, or over $130/ ton! The City of Detroit could have saved over $55 million in just one year if it had never built the incinerator.

The total cost (tipping fee) for Detroit to "dispose" of less than 600,000 tons of trash in Fiscal Year 2005-06 (FY0506) is budgeted at $81,129,823, which is over $135/ton to burn or bury trash. This does not include the cost of trash collection, which is an additional $11,445,983. Compare this to the nearby communities of the Southeastern Oakland County Resource Recovery Authority (SOCRRA) whose members paid an average of less than $29/ton for a combination of disposal and recycling services during FY0405.

The single largest debt of the City of Detroit is its bill for the construction and additional pollution controls for Detroit's trash incinerator. The debt payment owed to Comerica Bank and the Bank of New York for Fiscal Year 2005-06 (FY0506) is estimated at $67.4 million. Detroit's contract with GDRRA and debt on the incinerator is for 20 years (1989-2009) so the city will have wasted more than one billion dollars for building and operating the incinerator. All of the current contracts for operation and debt of the incinerator end in 2009.

To further complicate things, in 1991 the City of Detroit was also facing a deficit. GDRRA sold the Detroit Incinerator for $634.9 million to Philip Morris Capital Corp. (tobacco) and Aircraft Services Corp. (a subsidiary of General Electric). Detroit received $54 million from the sale but is now beholden to these private interests in a sale-leaseback agreement. If Detroit wanted to end the use of the incinerator for trash "disposal" before 2009, the city would have to pay these private interests an early closure penalty. If it were not for this penalty the city could close the incinerator, finish paying off the construction debt and still possibly save some money by landfilling the trash instead, or better yet implementing comprehensive recycling.

The Detroit Incinerator has also been an environmental disaster. *It is a major source of air pollution for the region. The latest readily available data (1999) from the U.S. Environmental Protection Agency ranks the incinerator #6 of 124 major sources in Wayne County for nitrogen* *oxides (1,444 tons). Nitrogen oxides create ground-level ozone (smog) and contribute to global warming. The incinerator is also ranked #8 of 106 major sources in Wayne County for sulfur dioxide (170 tons). Both nitrogen oxides and sulfur dioxide aggravate respiratory illnesses (such as asthma) and contribute to acid rain.*

How does SOCRRA keep its costs so low? Under the City Management contract with GDRRA, Waste Management delivers SOCRRA's non-recyclable trash to the Detroit Incinerator at a cost of only $10.45/ton! The residents of Detroit not only have to breathe the pollution from the incinerator but they subsidize the cost of burning Oakland County's trash as well.

There will be an opportunity for a better alternative when all of the contracts and debt end in 2009. Whoever is elected the next mayor of Detroit will decide whether the city will continue the dirty and expensive practice of running an incinerator or turning to the cleaner and cheaper practice of comprehensive recycling.

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For A Clean and Safe Detroit: Close the Country's Largest Incinerator By Mary Beth Doyle and Brad van Guilder

(The Ecology Center publication From the Ground Up, March 2002)

When Kwame Kilpatrick was campaigning in last fall's mayoral race, he called for new ideas to improve Detroit's public services and address severe financial problems. A coalition of neighborhood and environmental organizations are offering the new Mayor a plan to do both, and to clean the City's air at the same time. The Ecology Center, Detroiters Working for Environmental Justice, and 10 other groups are calling for the City to close its trash incinerator and start a comprehensive recycling program. This plan would make better use of resources, reduce air pollution, and save the city money.

Detroit began building its incinerator in 1986, despite protests from environmental justice and public health activists, who were dismayed to see the city invest so heavily in a polluting technology. "We knew then that this was a bad idea for the environment, and we've since learned that it's a bad idea financially as well," said Ed McArdle, Detroit-area resident, Ecology Center Vice-President, and Sierra Club activist.

At the time, proponents considered incineration to be a clean and affordable alternative to landfills, but the project quickly turned into another expensive embarrassment for Detroit. Today, the Detroit incinerator is the largest of any municipality in the U.S. It burns more than 700,000 tons of waste per year — about 3,000 tons per day — of which 60% comes from Detroit. The City will spend about $77 million this year to burn and landfill its trash, nearly ten times the amount paid per ton by its suburban neighbors.

A Question of Health and Justice

The incinerator sits in the heart of the city where I-75 and I-94 intersect, in a low-income, predominantly African-American neighborhood. The surround-ing community is already exposed to pollutants from numerous sources in the area, including Michigan's only commercial medical waste incinerator, the GM Poletown plant, and two major highways.

It is in this overburdened community that Detroit decided to build the incinerator, which is legally allowed to release more than 25 tons of hazardous air pollutants and more than 1,800 tons of other pollutants, including sulfur dioxide, nitrous oxide, particulate matter, mercury, and lead, every year.

A recent Michigan Senate report cited municipal waste incinerators as the second largest source of mercury contamination in Michigan and a threat to the Great Lakes. Municipal waste incinerators are also a major source of dioxin, a persistent chemical that is toxic even in very small amounts. Dioxin is a hormone disrupter that can cause cancer as well as reproductive and developmental effects.

The community already has its share of health concerns. The neighborhoods surrounding the facility have one of the highest rates of elevated blood lead levels in the city. Almost 40% of Detroit children with elevated blood lead levels live within 10 zip code areas in the center of the city, including the area containing the incinerator. Many pollutants from incinerators can affect lung function and trigger asthma attacks. Detroit has one of the highest asthma rates in the country — three times the national average — and ranks third in asthma-related deaths. It leads the nation for asthma death rate among African Americans.

Regardless of whether these health problems are caused by emissions from facilities like the Detroit incinerator, the prevalence of these illnesses within the community makes this population more susceptible to harm from the pollutants emitted by the incinerator.

Who Profits?

The Greater Detroit Resource Recovery Authority (GDRRA) is the public body responsible for the bond repayment and operation of the facility, and Covanta Energy Corporation (formerly Ogden) oversees day-to-day operations. However, the incinerator is owned by Philip Morris Capital Corporation, a subsidiary of the tobacco conglomerate. Philip Morris bought the facility in 1991 and leases it back to the city.

"It's been well-documented that cigarette companies target minority communities like Detroit with their billboards," said Donele Wilkins, Executive Director of Detroiters Working for Environmental Justice. "It's ironic Philip Morris is targeting our community with the country's largest municipal waste incinerator as well."

Continued operation of the incinerator is also an economic disaster for the citizens of Detroit. In the current fiscal year, Detroit will spend $77 million to burn and landfill approximately 600,000 tons of trash.

This $130-per-ton cost is an Enron-sized scandal, given the City's fiscal problems and the disposal costs paid by its suburban neighbors. The Southern Oakland County Resource Recovery Authority (SOCCRA) recently received a bid of less than $14 per ton to dispose of its trash at Republic Industries' Carleton Farms Landfill in Sumpter Township. The City of Ann Arbor pays even less for its combination of landfill disposal, recycling, and composting.

Were Detroit to shut down its incinerator in favor of landfill disposal, the City would probably receive bids even lower than SOCCRA's because of its large volume of trash. Even if Detroit couldn't beat SOCCRA's price, and even if it was forced to pay off the remaining $400 million on the incinerator bonds, the City could possibly save $20 million per year. If the City added a comprehensive recycling program to the effort, the savings could reach as high as $25 million per year.

Cut Your Losses, Mr. Mayor

In January, community leaders and environmentalists from around the state spoke out against the facility at a Michigan Department of Environmental Quality (MDEQ) public hearing about the facility's Renewable Operating Permit. Citing incomplete €les, inadequate public notice, and environmental justice concerns, person after person spoke up to demand that the Department deny the permit.

But even if MDEQ does grant the permit (there is no case where a Renewable Operating Permit has been denied), environmentalists and Detroit community leaders plan to continue their efforts to shut down the incinerator. "Incineration is not good for public health and it is not good for the city's bottom line," said Ed McArdle. "It is time to make Detroit an incinerator-free zone."

The incinerator continues to pollute low-income neighborhoods and drain money out of city coffers. Now it's time for Mayor Kilpatrick to cut the City's losses on the plant – right here, right now.

Appendix VIII

Additional Information Accessible on the Internet

- Waste Management and the Environment III (Witpress.com)
- Comparison of Leachate Quality from Aerobic and Anaerobic municipal Solid Waste Bioreactors
- Quality and Quantity of Leachate in Aerobic Pilot Scale Landfills
- Bioreactor Landfills, An Overview Perspective by John Pacey (Emcon Engineering) [MSW Management Magazine]
- Solid Waste Management and Global Warming (SPREP)
- Aerobic landfill bioreactor United States Patent 6364572
- Degradation of Municipal Solid Waste in Simulated Aerobic and Anaerobic Bioreactor Landfills
- Operational Characteristics of Two Aerobic Landfill Systems
- Comparison of Aerobic and Anaerobic Biotreatment of Municipal Solid Waste, Peter Zawislanski
- The Bioreactor Landfill, Waste Management Bioreactor Program
- Effect of Aeration on Fresh and aged Municipal Solid Waste in a Simulated Landfill Bioreactor-Ryerson University
- Leachate Recirculation or Clean Water Addition: A Comparative Study
- The Status of Aerobic Bioreactor Landfills in the US, NCWANA Debra Reinhart, Nicole Berge, Mark Hudgins
- Effect of Combined Air Injection and Leachate Recirculation on Biodegradation of MSW
- Interim Guidelines for the Production and Use of Compost in Ontario 1749e.pdf
- 'Draft' Guidelines for Aerobic Composting Facilities and Compost Use (Ontario)
- Operating Landfills as Bioreactors to Decompose and Stabilize Solid Waste, Timothy Townsend
- U.S. EPA Project XL: Yolo County's Accelerated Anaerobic and Aerobic Composting (Full Scale Controlled Landfill Bioreactor) Project
- Reducing Potential for Climate Effects of Non CO2 Greenhouse Gases
- Aerobic bioreduction of municipal solid waste landfill mass. U.S. Patent 6481929
- Updated Research Report on Bioreactor Landfills, Landfill Leachate Recirculation and Landfills with Methane Recovery
- Characterization of Landfilled Municipal Solid Waste Following IN SITU Aerobic Bioreduction
- Municipal Partnership in the Ottawa Valley Chooses to Walk Lightly on the Environment
- Using Municipal Solid Waste Compost
- Innovative Uses of Compost, Erosion Control, Turf Remediation, and Landscaping
- In Situ Municipal Solid Waste Composting Using an Aerobic Landfill System
- The Aerobic Landfill System
- Biodegradation Won't Solve the Landfill Crunch
- How to Sustain your Landfill
- Composting Council of Canada, 25 Questions and Answers about Composting
- Composting Regulations and Guidelines Across Canada
- A Methodology to Estimate the Carbob Off Set Potential of Composting Bio-Degradable Municipal Solid Waste
- The next sustainable revolution in solid waste management: bioreactor landfills (American Public Works Association)
- Optimization of Landfill Mining, R .J. Murphy
- Aerobic landfill process spreads in the Southeast with a new site in TN
- Preserving Resources through Integrated Sustainable Management of Waste (Landfill Mining)
- Landfill Reclamation EPA 530-F-97-001 July 1997
- Recycling the landfill: the mining of disposal sites, Tom Watson
- Discussion Document and Draft Regulations: Landfill Mining/Reclamation Regulations (Massachusetts)

- Assessing the Opportunities of Landfill Mining
- Evaluation of the Collier County Florida Landfill Mining Demonstration
- Methods of improved landfill mining ISSN 0734-9750
- Exploring the Economics pf Mining Landfills (Waste Age)
- Analysis of Municipal Waste Sites and Landfills in the United States
- Guidance Note on Recuperation of Landfill Gas from Municipal Solid Waste (World Bank working paper)
- Landfill Space Reuse Robert Spencer
- ACUA Wins International Award for Landfill Management
- Bioreactor Landfills: An Idea whose Time has Come. MSW Management (Christopher Campman, Alfred Yates)