INTEGRATED WASTE MANAGEMENT: A SUSTAINABLE FUTURE

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ABSTRACT

Integrated Waste Management: A Sustainable Future

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Integrated waste management is a process in which managers of municipal solid waste can utilize waste as a resource rather than a burden. It utilizes such treatment strategies as reduction, reuse, recycling, conversion and waste-to-energy. Through analysis of a targeted waste stream, managers can inventory potential resources to be recovered for further use. As a process, it can minimize economic cost, and detrimental environmental and social impact. As a strategy it is adaptable, and can be applied to any waste situation in any locale, through proper planning and implementation.

This essay explores the different components of and requirements for integrated waste management. Economic, environmental and social concerns of waste treatment methodologies are discussed. The idea of sustainable development is introduced and applied to integrated waste management. Finally an argument is presented to suggest that integrated waste management meets some of the criteria for sustainable development. As such, this strategy is dynamic, adaptable and responsible; it is the future of municipal solid waste treatment.

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INTRODUCTION

Growing world populations are producing ever increasing amounts of solid waste. In America alone, the annual per capita production of municipal solid waste (MSW) exceeds half a ton (USCOTA 1989). Landfills are closing at alarming rates, at capacities exceeding design standards. Many are failing to contain hazardous leachates. Mass burn incineration facilities are being canceled as public acceptance of such facilities diminishes. Air and water are being affected by outdated waste treatment facilities. In response to air and water quality issues, the development of alternative waste management methods has taken place.

"An increasing number of communities have [has] begun to view waste as a potential resource instead of a disposal burden. Many community leaders have used a multi-faceted approach to planning and implementing solutions to solid waste management problems" (Golob 1989). In order to dispose of MSW, policies have been adopted to reuse, recycle, compost, incinerate or landfill waste materials. While each method alone may be an effective means of waste management, an integrated approach combining all of these disposal strategies may be the most economically and environmentally friendly means of handling MSW.

Integrated waste management (IWM) combines recycling, composting and waste-to-energy technologies. By removing the compostable organics, recyclable inorganics and hazardous materials, volume is reduced and energy content of the remaining material is increased. This material can then be incinerated with energy production and further volume reduction as a goal. When pre-treated, MSW quantity and toxicity are reduced and facility life span is increased. Revenues from recycled materials and energy production can offset the operating costs associated with MSW sorting and pretreatment (Shortsleeve and Roche 1990).

A recent strategy for waste management involves a 4-part hierarchy combining different solutions, "some high-tech and some low-tech, with the priority: 1) waste reduction; 2) recycling; 3) waste-to-energy; and 4) land disposal" (Taylor 1989). These concepts can be applied to MSW management in a sequential manner. By analyzing a municipality's waste production and composition, materials can be targeted and treated with the appropriate methodology.

The U.S. Congress Office of Technology Assessment (USCOTA 1989) found that a waste hierarchy can only be meaningfully applied to MSW when waste is managed on a material by material basis rather than as mixed MSW. The USCOTA suggests that waste prevention and materials management is a comprehensive rather than an integrated approach, because MSW options are considered before choosing and implementing them in some presumed hierarchy. However, combining concepts and implementing available technology in a process tailored to a municipality's needs should prove beneficial regardless of its title. The reason that the USCOTA separates prevention from management is to ensure that adequate attention is focused on each. I feel that prevention **is** part of management because it addresses the **potential** for waste production and applies management techniques for reduction.

This essay will first explore the different components and requirements for IWM. Then environmental and social concerns associated with each component will be covered. Economic, social, and environmental costs will be discussed. The idea of sustainable development will be introduced, and applied to IWM. Finally the findings of my research will be presented as a case for IWM as sustainable development.

MUNICIPAL SOLID WASTE

MSW is defined by USCOTA (1989) as post-consumer solid wastes generated at residences (e.g., single-family units and apartment buildings), commercial establishments (e.g., offices, retail shops, restaurants) and institutions (e.g., hospitals, schools, government offices). These wastes may be categorized as either materials or products as shown in Figure 1.

MUNICIPAL SOLID WASTE

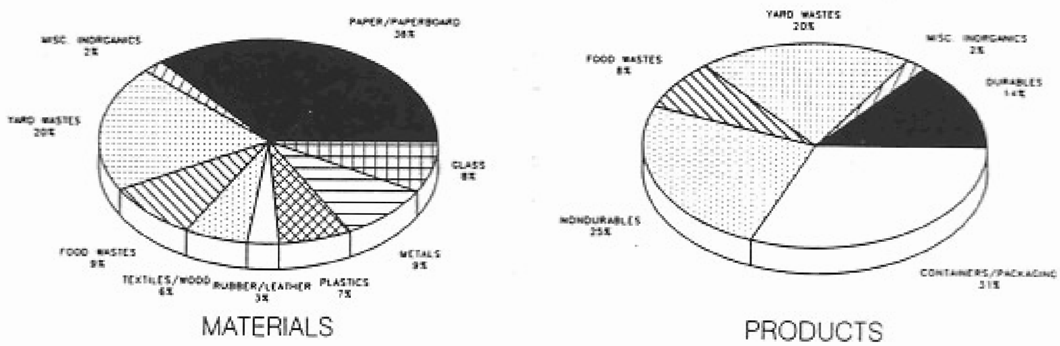

Figure 1. Estimated Portions of Materials and Products in MSW, 1986, by Weight.
Source: USCOTA 1989, Facing America's Trash: What Next for Municipal Solid Waste?

The components of MSW can vary by season, location and socioeconomic conditions. Nevertheless, there are some trends visible for the composition of MSW. Table 1 shows the results of a nationwide study to determine the makeup of MSW. Paper and paperboard products comprise the largest category of materials in MSW (USCOTA 1989). Yard and food wastes make up the second largest category, with metals and glass, and plastics the third and fourth respectively.

Table 1. A Comparison of Estimated Percentages of Different MSW Components, by Weight.

MATERIALS	MEAN	RANGE
Total paper	38.8	29.9-45.9
Newspaper	6.3	4.3-8.1
Corrugated	7.9	4.7-13.1
Mixed	21.9	19.6-25.2
Magazines	0.7	0.7
Total metal	4.9	1.5-9.4
Aluminum cans	0.9	0.8-1.2
Miscellaneous aluminum	0.7	0.2-1.6
Other non-ferrous	1.0	0.0-3.4
Total glass	7.8	3.6-12.9
Glass containers	6.4	6.1-6.6
Total plastic	8.8	5.3-12.6
Plastic film	3.1	3.1
Plastic containers	0.9	0.7-1.0
Yard waste	18.2	0.0-39.7
Food waste	14.7	1.3-28.8
Wood	2.6	0.7-8.2
Textiles	3.4	1.1-6.2
Rubber	0.4	0.0-1.0
"Not elsewhere classified"	9.2	3.8-16.6

Adapted from: USCOTA 1989 Facing America's Trash: What Next for Municipal Solid Waste?

The components of MSW can present some risks during the treatment of waste products:

- emissions and ash from incinerators;
- emissions and leachates from landfills; and
- emissions, effluent and sludge residues from recycling.

Some of these are created when the organic portion of MSW (e.g., yard wastes, paper, and plastics) is processed, burned, or decomposed. Others stem from the metals and organic chemicals contained in products discarded in MSW - in "household hazardous wastes" (e.g., solvents, paints, batteries, and cleansers) and other products (e.g., metal additives in plastics) (USCOTA 1989).

By understanding the variability of the components in the waste stream, and utilizing a regular sampling program, waste managers can adjust waste treatment methods to achieve the most efficient and economic disposal means possible through integrated waste management.

COMPONENTS OF INTEGRATED WASTE MANAGEMENT

REDUCTION

One of the top priorities in the waste management hierarchy is reduction, or prevention. Waste reduction at the source has to be considered the most direct form of preventing, avoiding or reducing the generation of wastes (Blumberg and Gottlieb 1989). MSW prevention reduces the quantity of discarded products before the products are purchased, used and discarded (USCOTA 1989).

Reducing the quantity of discarded materials would extend the useful life of existing and future waste management facilities and allow new replacement capacity to be developed at a slower rate (Levenson 1990). Other benefits include: fewer environmental problems with waste management, lower waste management costs, increased conservation and efficient use of resources and increased public confidence in government MSW policies and in industry (USCOTA 1989). While this option may seem "only logical" and is the most popular among state regulatory agencies, environmental groups, the media and the general public, it is not without problems.

There are two basic routes to MSW prevention: 1) manufacturers can change the design of products and the way they are packaged, and 2) consumers can alter purchasing decisions about existing products and the way they use and discard products (USCOTA 1989).

Both strategies are being promoted and directed at those who are responsible for disposal: local governments. However, they often ignore reduction as they are powerless to do much about it. Federal and state governments have the power to introduce legislation to require reduction and create markets in the commercial sector for recyclables (Taylor 1989). But they don't. The burden of reduction is typically left on the shoulders of local governments. Furthermore, local governments can do little to influence manufacturing decisions or consumer buying patterns. Most products are marketed in more than one state, and local officials cannot easily mandate changes in products that flow in interstate commerce. Manufacturers that market products in more than one state would be hard pressed to meet various state and local requirements for product composition and packaging (Levenson 1990).

The lack of incentives is another problem for reduction. Manufacturers have little incentive to consider the problems or costs of MSW disposal when they design and make a product because most products do not become waste until long after leaving a factory (USCOTA 1989). The costs of disposing of a product have been considered external to the costs of production. Attempts to internalize some or all of the costs of disposal might have a major impact on the reduction of product wastes. Individual consumers have little or no economic incentive to consider the implications of their purchasing and consumption patterns. "Moreover, reducing the quantity of MSW is somewhat at odds with the demand for convenient, disposable, and for that matter, all types of products" (Levenson 1990). Waste reduction can be targeted at packaging (materials used to prepare finished good for shipment, distribution, storage, merchandising and end use), single-use products (diapers, plastic and paper plates, cups and utensils, razors, cameras and flashlights), certain paper uses (direct mail advertising, newspaper supplements), yard wastes (composting would eliminate these from entering the MSW waste stream) and durability and repairability of products (these delay the discarding of a product)(USCOTA 1989; Levenson 1990). Tradeoffs that must be anticipated and expected by the consumer include: less convenience, higher production and purchase costs, and effects on recycling (plastics may be lighter and less bulky but are less recyclable than the paper products they replace)(Levenson 1990). Table 2 shows how consumers can influence MSW generation in an effort to reduce MSW.

Table 2. Ways in Which Consumers Can Influence MSW Generation.

- buying items that are reusable instead of disposable
- selecting product brands that are durable or repairable
- buying in bulk, large sizes or concentrates
- buying lighter versions of products
- avoiding containers of mixed materials
- composting yard an food wastes in residential backyards
- buying fresh rather than pre-packaged fruits and vegetables
- donating usable but unwanted materials to friends or charities
- buying products that contain fewer potentially toxic substances
- reusing product containers and purchasing beverages in refillable bottles
- using home delivery of water instead of purchasing bottled water

Adapted from: USCOTA 1989 Facing America's Trash: What Next for Municipal Solid Waste?

REUSE

Reuse of materials in their original form has been around for centuries and still survives as a waste management strategy. Examples of reuse fall mainly into the container category: beverage bottles, home canning jars and packaging such as boxes and grocery bags. Other reuse items include cloth diapers and cloth rags. Reusable items can have multiple lives in their original form, thus conserving energy and raw materials.

"Petroleum-based products fundamentally restructured the consumer products industry, displacing a wide variety of reusable/recyclable materials" (Blumberg and Gottlieb 1989). Today's society has evolved into a throwaway society based on convenience. However, the rebirth of interest in reusing materials has been enhanced by an attitude shift toward more responsible resource utilization and waste management.

Legislation to mandate the reuse of packaging materials or "bottle bills" has been supported by citizens in Maine, Michigan, Oregon and Vermont. These bills created deposits on all soft drink and beer containers in order to stimulate their return. While supported by voters, bottle bills were opposed by the container producing industry. Reasons cited for opposition include historical mode of production choices, job loss and potential price increases. Consequently, only a handful of states have passed legislation requiring materials reuse.

RECYCLING

Recycling is the practice of using materials found in waste products to generate new products. Recycling was a "matter of survival" for early settlers and instrumental in war efforts during World War II (USCOTA 1989). Recycling is receiving great attention as MSW disposal problems increase. It can be a major contributor to the success of an IWM program.

"Recycling actually consists of three different activities: collecting secondary materials, preparing those materials for market, and the actual recycling of the materials by manufacturing new products" (USCOTA 1989). Recycling occurs on both the pre- and post-consumer level. Pre-consumer waste results from the manufacturing process, and most waste materials are recycled to reduce costs of materials procurement and disposal. Post-consumer waste results from the use of a product by the final consumer and from its ultimate disposal. IWM and MSW focus primarily on post-consumer waste.

Materials that can be recycled include: aluminum, batteries, glass, iron and steel, oil, paper and paperboard products, plastics, and tires. The top three recycled materials are aluminum, paper and paperboard, and glass (Blumberg and Gottlieb 1989). Table 3 shows the recovery of materials from MSW and the recovery rates as percentages. The national average rate for MSW recycling is 10% (USCOTA 1989).

Table 3. Recovery of Materials from Municipal Solid Waste, 1984.

MATERIAL	DISCARDS[a]	RECOVERY RATE (%)
Aluminum	2.1	28.6
Paper/paperboard	62.3	20.7
Glass	13.9	7.2
Rubber/leather	3.4	3.0
Iron/steel	11.3	2.7
Plastics	9.6	1.0
TOTAL	100.6	14.3

[a]1984 MSW figures, millions of tons
Adapted from: Blumberg and Gottlieb 1989 War on Waste.

Recyclable wastes can be collected in three ways: as mixed wastes, as commingled recyclables, and as separated recyclables.

Mixed Wastes

Mixed wastes are the most difficult and cost consumptive to handle. Processing mixed MSW involves removing oversized, explosive and damaging materials, reducing size, and component segregation. Materials are then marketed as separate stock. An advantages of processing mixed MSW is that no special collection system is needed to obtain the waste. Disadvantages include high energy needs, high maintenance costs, and potential health hazards to workers.

Commingled Recyclables

Commingled recyclables have been separated from other wastes and reasonably prepared by the consumer. While not separated into individual containers by material, all recyclables are placed in the same container for pickup. Once commingled recyclables are in the processing facility, the handling and preparation methods are the same as for mixed wastes. "The advantages of commingled collection are that some separation is already done and thus the amount of contamination that must be dealt with is reduced" (USCOTA 1989). A disadvantage is that it requires a different collection system and is dependent on public participation.

Separated Recyclables

Separated recyclables are separated by the consumer for pickup at curbside. Each material is placed into its own container. Collection is often done by special compartment vehicles. Once collected, further processing includes contaminant removal and baling of individual materials. The big advantage to separated recyclables is that much of the labor has already been done. Disadvantages are that of commingled recyclables; a different collection system is required and public participation is critical to success. MSW is often treated at a centralized location or Materials Recovery Facility (MRF). Methods and technologies vary, but the main objectives are "to sort recyclable materials, remove contaminants, and prepare materials for marketing" (USCOTA 1989).

Aluminum

Aluminum recycling consists mainly of diverting used beverage containers (UBC's) from the waste stream. Aluminum can recovery in the U.S. in 1988 was approximately 55% (USCOTA 1989). The remaining aluminum that is recycled comes from foil and other containers, appliances, lawn furniture, and other items.

"In the United States, the recovered scrap metal is either returned to the domestic aluminum industry to be recycled into semi-fabricated products (e.g., can sheet) or castings, used as an oxidizing agent in steelmaking, or is exported" (USCOTA 1989).

Paper and Paperboard

The majority of waste papers recycled include old newspapers, old corrugated containers, and mixed grades. "Recovered waste paper, or secondary fiber, is used to produce new paper products, construction materials, and miscellaneous products such as animal bedding, insulation, and cushioning" (USCOTA 1989). Waste paper recovery in the U.S. in 1987 was 28.5%.

Glass

Waste glass, or cullet, is mainly recovered from beverage and food containers. The cullet is used in the manufacturing of new containers.

"Because of chemical differences, container cullet generally cannot be used to make most types of glass other than new containers and fiberglass" (USCOTA 1989). Additionally, cullet is mixed with virgin materials due to difficulties in using 100% cullet to make new containers. These limitations account for a recovery rate in the U.S. in 1988 of 15% (USCOTA 1989).

Iron and Steel

Sources of iron and steel in MSW include food and beverage cans, major and small appliances, toys, tools and furniture. Scrap is processed and melted into new steel or steel alloy products. The majority of MSW recovered ferrous scrap consists of "tin cans" and appliances; these materials in 1986 were recovered at a rate of only 3.6% (USCOTA 1989).

Plastics

"Plastics recycling is mostly confined to post-consumer polyethylene terephthalate (PET) and high-density polyethylene (HDPE) containers" (Garino 1989). These materials are used directly as replacements for virgin plastic resins and are used to produce containers as well as a multitude of other plastic products. Additionally, commingled plastic waste is converted into a plastic alloy used in making such products as a lumber substitute, flat plastic sheets and other items. Despite these various uses, plastics recycling in the U.S. in 1986 was less than 1% (USCOTA 1989).

Other Materials

Other recyclable materials include batteries, oil, and tires. Household batteries can be recycled to recover metals such as mercury, steel, silver, zinc, nickel, and cadmium. Lead-acid automotive batteries are recycled for lead and plastic casings. Used motor oil is utilized mainly as a fuel, although about a third of it is re-refined. Waste tires have been reprocessed into specialized industrial products and household items. Tires that have been broken down into fine particles have been used to replace virgin rubber in carpet backing, asphalt, and friction break materials. Scrap tires have also been converted to gas, oil, and char through pyrolisis, and used as a supplementary fuel (USCOTA 1989).

CONVERSION

Conversion of wastes involves both chemical and biological techniques, such as pyrolysis, hydrolysis, and biological decomposition. Useful materials that can be converted from wastes include: oils and gases, glucose, alcohol, and compost.

Pyrolysis

Pyrolysis is the chemical decomposition of combustible solid wastes by heating without oxygen. Thermochemical reactions produce water, gases, oils, tars, and chars by "cooking" waste at temperatures from 900 to 1200°

F in the absence of oxygen. The gases and oils are combustible and can be used as fuels. The tars can be mixed with asphalt; slags can be used as concrete aggregate, fill and road -base materials. The chars can be compressed and used as a charcoal substitute (Clark and Gillean 1981;USCOTA 1989).

Hydrolysis

Cellulosic wastes such as yard and food materials can be converted to useful products through hydrolysis. Glucose can be obtained by a sulfuric acid treatment at 450° F. The sugars produced can be further converted to ethyl alcohol which is combustible, and single-cell proteins which could be used to supplement animal feeds (Wiles 1981).

Biological Decomposition

Organic materials (i.e., yard, food, animal, and paper wastes) can be converted to compost and methane gas through biological decomposition.

Composting uses aerobic bacteria and fungi to decompose organic material. "To maximize the rate of microbial activity, the composting process must be designed to properly control factors such as temperature, oxygen and nutrient availability, physical substrate, moisture, and pH" (USCOTA 1989). The resulting soil-like product can be cured and used to improve soil structure. It can also be finished by screening, pulverizing, destoning, pelletizing, and/or crumbling and mixed with other products or soils to make growing media.

Anaerobic bacteria are used to convert organic wastes to methane gas. Digester reactors that control temperature and pH yield carbon dioxide and methane gas which can be purified and used in the same manner as natural gas.

WASTE-TO-ENERGY

Incineration of municipal solid waste results in a volume reduction of greater than 90% (Palombella and Kennedy 1989). In addition to volume reduction, energy recovery can be accomplished. Technologies have evolved for converting waste to energy and involve such methods as unprocessed waste combustion (mass burn), processed refuse derived fuel (RDF), pyrolysis, methane gas conversion, and small modular combustion (SMC)(Wiles 1981).

According to Palombella and Kennedy (1989), "In the 1980's, impressive improvements to incineration technology were made in the following areas:

- combustion air distribution
- boiler design to minimize flame impingement on tubes and to reduce deposit formation on tubes
- process control (programmable logic controllers)
- air emissions control with lime injection and fabric filters."

The USCOTA (1989) and Palombella and Kennedy (1989) described some advantages and disadvantages of incineration in conjunction with waste-to-energy programs. Advantages include:

- volume reduction
- cost recovery (energy sales)
- minimize environmental impact
- pathogen and toxic chemical destruction
- upgradability with modifications to implement best available technology.

Disadvantages include:

- high startup capital and operating costs
- reliability of facilities
- siting difficulties.

Mass Burn

"Mass burn systems burn unprocessed, mixed MSW in a single combustion chamber under conditions of excess air" (USCOTA 1989). As the waste is combusted, boilers recover heat and produce steam. The steam is then used to generate electricity.

Refuse Derived Fuel

RDF systems process MSW into a homogeneous fuel by mechanical means. "Several types of RDF can be made - coarse, fluff, powder, and densified. These differ in the size of the particles and whether or not the material is compacted under pressure (densified) into uniform pellets, briquettes, or similar forms" (USCOTA 1989). RDF can be burned in plants specifically designed to burn RDF or used as a supplementary fuel in oil or coal fired plants. By processing MSW into RDF, energy content of the waste is increased, toxicity of the resulting residues is decreased, and equipment damaging elements are eliminated or reduced (Shortsleeve and Roche 1990). The energy obtained from incineration of RDF can be used to produce electricity as well.

Pyrolysis and Methane Production

Fuels that have been created through chemical and biological decomposition can be fired in boilers, used in engines and turbines, and used as a supplementary fuel.

Small Modular Combustion

"Modular systems are small, factory-fabricated plants, generally custom-designed to fit a particular application" (USCOTA 1989). They utilize unprocessed MSW as a fuel in a two chamber combustion system. The first chamber is operated in an oxygen deficient atmosphere causing volatilization of gases. In the second chamber the gases are combusted in excess oxygen. Processed RDF can also be combusted in these systems. Advantages of SMC systems are that they can be custom designed to utilize a particular waste stream and they have the ability to upgrade as waste flows increase. A disadvantage is that wastes are often not completely combusted resulting in greater ash quantities and less efficient energy recovery.

ENVIRONMENTAL CONCERNS

Disposal methods are not without environmental impacts. Incineration can produce hazardous air emissions in the form of gases and ash. Landfills can produce leachates which contaminate ground and surface waters and potentially explosive methane gas. However, IWM technology can restrict these adverse impacts to levels within limits set by the Environmental Protection Agency.

PROCESSING

Environmental impacts resulting from processing MSW include odors, dust, and noise produced at the processing facility. In addition, washing recovered materials destined for recycling produces wastewater which may contain hazardous chemicals. In a well designed processing facility, full enclosure of the processing area, separate sorting and mechanical equipment areas, and filtration systems can reduce noise, odors, and dust (Smith 1989).

CONVERSION

It is generally accepted that recycling reduces pollution. "In particular, if recycled products replace products made from virgin materials, potential pollution savings may result from the dual avoidance of pollution from manufacturing and from subsequent disposal of replacement products made from virgin materials" (USCOTA 1989). Additionally, and perhaps most importantly, recycling and conversion eliminates the adverse environmental impacts of obtaining raw materials for manufacture.

Ferrous Materials

Recycling steel and iron can produce solid wastes, air emissions, and wastewater. Contaminants that can be found in these wastes include phenols, ammonia, sulfur dioxide, airborne particulates, suspended and dissolved solids, heavy metals, and oxygen-demanding substances. Levels of heavy metals such as lead, cadmium, and chromium can be higher due to reprocessing of ferrous scrap of mixed composition. High levels of particulates can be emitted if the scrap contains high concentrations of dirt, organic matter, and alloys. The levels of these contaminants however, are usually lower than those produced by virgin material processing. Sorting and reprocessing of similar ferrous materials, and thorough cleaning of scraps can lower the levels of heavy metals and particulates that are produced.

Aluminum

Aluminum reprocessing also produces less hazardous materials than production from virgin materials. Aluminum scrap may contain painted labels, plastic, oil, grease, dirt, and organic matter. When these materials are combusted during the remelting process, air emissions can contain particulate matter and gases, particularly chlorides and oxides, and acid and chlorine gases. In general, the impacts from recycling are less than those associated with raw materials acquisition and production.

Paper

Paper recycling provides the least advantage to reducing impacts. While it reduces the need for raw materials, (most recycled paper products contain some raw fiber), the fiber extraction process may produce higher levels of pollutants than the primary manufacturing process. Heavy metals from printing inks can be present in wastewater and de-inking sludge. Dioxins can be produced from the bleaching process. Sludges and liquors from the pulping and bleaching process are often burned to recover energy and reduce disposal costs. Air emissions can include particulate matter and gases such as chlorine, chlorine dioxide, sulfur dioxide, and hydrogen sulfide. The biggest advantage to paper recycling is the reduced need for virgin materials.

Plastics

Environmental impacts from plastic recycling are less than those from primary plastics production. Plastic products are made from resins, and, "once a resin is produced, the environmental risks associated with fabricating products from the resins are the same whether the resin is produced from virgin or secondary materials" (USCOTA 1989). Recycling can eliminate the air emissions, wastewater, and solid waste created by primary production. The main concerns with reprocessing plastics are volatile air emissions produced during the heating of plastics, and residues in rinse water for cooling the plastics. These emissions can be controlled through filtration of heating effluent and using closed cooling systems that reuse cooling and washing water.

Composting

Composting impacts can vary depending on whether the waste is mixed MSW or separated organic wastes. Both can produce odors during the process and residual organic chemicals in the finished product. Mixed MSW has shown to contain higher concentrations of heavy metals than sorted materials. These organic chemicals and heavy metals can leach out of the finished product or be taken up by vegetation grown on the compost. Further research is needed to determine the rates of discharge of these contaminants into the environment. Another concern is the survival of pathogens in composted wastes, particularly those that are co-composted with sewage sludge. A simple remedy for this problem is pasteurization of the compost prior to the release of the finished product.

WASTE-TO-ENERGY

The two major impacts from WTE facilities are toxic air emissions and ash production and disposal. These impacts can be minimized through available technology, and "the net environmental effect of waste-to-energy conversion appears to be positive with respect to air pollution" (Wiles 1981).

Toxic air emissions associated with incineration include carbon monoxide, particulate matter, nitrogen oxides, dioxins and furans, acid gases, and heavy metals. Older mass burn facilities have higher emissions than RDF systems, but newer high-tech facilities have not shown a significant difference between mass burn and RDF facilities. Newer facilities show a definite improvement in emissions over older facilities. Pollutant in air emissions can be controlled by materials separation prior to combustion, temperature control and additional combustion of gases, and filtration with pollution control equipment.

Ash is what is left after combustion takes place. Fly ash is small, light particulate matter; bottom ash is coarse uncombusted or partially combusted material. Metals and organic chemicals tend to be concentrated in ash materials posing disposal problems, particularly if concentrations are high enough to warrant hazardous material classification. The main concern with ash disposal is the potential leaching of the metals and organic chemicals into ground and surface waters. The potential for leaching has been minimized by using lined ash monofills, melting the ash into a glass-like substance, and mixing ash with cement and road materials.

LANDFILLS

Landfills produce visible as well as hidden environmental impacts. The most apparent impact is the "mountain" of waste resulting from landfilling operations. Many landfills are unsightly, ugly monstrosities that do not blend in well with the surrounding environment. Current reclamation technology is being applied to these sights with landscaping and revegetation providing remedies for the eyesore. Other impacts include the leaching of metals, organic chemicals, and pathogens into ground and surface waters, and the emission of methane gas into the atmosphere. Numerous organic chemicals in gaseous forms can be emitted as well. Toxic leachates can be controlled with leachate collection and treatment systems. Methane gases can explode as well as have a potential effect on global temperatures. These gases can be collected and combusted for energy recovery or flared to convert it to carbon dioxide. A properly designed, sited, constructed, and operated landfill should minimize adverse environmental impacts to the environment (USCOTA 1989). Additionally, landfills and monofills can be designed specifically for the anticipated waste stream, and emission controls can be implemented for maximum containment.

SOCIAL CONCERNS

Social concerns related to IWM can range from threats to public health, public acceptance of management plans and facilities, and public participation in waste management activities.

HEALTH CONCERNS

The health of individual workers as well as the public can be threatened by IWM practices. These threats can be minimized through proper planning, design, and management of treatment practices.

Many of the management options require considerable processing of materials prior to final use. Processing is often a combination of manual and mechanical methods, accomplished at a waste processing facility. Workers performing processing duties can be exposed to health hazards through contact and inhalation. Airborne exposure to chemicals, pathogens, dust, and odors derived from MSW can lead to short term and long term health effects. Noise from machinery can also be a hazard. Physical injuries can result from direct contact with broken glass and metal.

Additionally, explosions can occur within size reduction machinery sending shrapnel towards operating personnel.

The health impact to the individual can be minimized through design of processing facilities. Full enclosure of sorting and processing areas can allow control of airborne contaminants and noise. Ventilation and filtration systems can limit exposure time to airborne contaminants. Noise dampening design and containment of processing machinery coupled with adequate personal hearing protection can minimize hazardous noise exposure. Direct contact to contaminated materials can be minimized by wearing proper clothing to limit skin contact. Materials size reduction machinery has been designed to control explosions; sorting and removal of potential explosive materials prior to reduction can virtually eliminate explosion hazard.

Communities adjacent to waste processing facilities are subject to the same health hazards as workers. Air emissions can include chemicals, metals, gases, odor, and particulates. Noise and transportation of MSW through communities can pose hazards as well. Reducing the health impact to the worker using the aforementioned methods also decreases the risk to residents of surrounding communities. However, landfilling and WTE can produce some additional emission problems as mentioned in the environmental concerns section. Advanced pollution control technology continues to limit leachates from contaminating water and minimize emissions from contaminating air.

PUBLIC ACCEPTANCE

Public opposition to IWM plans and location of facilities may be the biggest impediment to IWM success. Location of facilities are hampered by the not-in-my-backyard (NIMBY) syndrome. The NIMBY attitude is provoked by misperception of risks associated with IWM methodologies and impacts to values. Education about real risks, options, and responsibilities can alleviate some of the fears associated with IWM.

The primary cause of public opposition "stems from a lack of confidence in the safety of a proposed facility and the uncertainties associated with its regulation and reliable operation" (USCOTA 1989). The public lacks a trust in the credibility of those who make waste management decisions: the government and experts. The highest safety standards and spotless operating records are of little use to the public if trust is not present. Data are meaningless if the public does not believe they are accurate representations of real situations. Most people tend to remember the rare failure of an emissions control system or other process than notice the routine uneventful operation the rest of the time. Statistical models that predict the operation of a proposed facility are usually ignored as the memory of outdated, ugly, imposing waste management facilities fill our minds. Perceived risks often take priority over real risks because we tend to dwell on what we see and can comprehend, rather than what is not tangible and may be predicted (Freudenburg 1988). Another barrier to facility siting is the idea of equity (the distribution and impact of risks). It is inevitable that facilities will be sited in rural settings. As most of MSW is generated in urban settings, the perception "that an urban problem is being imposed on its rural 'neighbor'" (McGee 1989). Surrounding residents of a rural waste management facility live with the risks while the generators of the majority of the waste are not responsible for their own waste generation. Value changes also enhance the NIMBY syndrome. MSW processing facilities affect the aesthetics of surrounding areas by placing unattractive sights (buildings, smokestacks, landfills) within viewsheds of surrounding residents. Property values may also decrease with the installation of an MSW treatment site.

PUBLIC PARTICIPATION

In order to overcome perceived risks, communication, education, and management are essential. In order to have better communication between the scientific community and the general public, tools are needed to clarify the differences between perceived and real risks (Freudenburg, 1988). Ellis (1989) sees these tools as openness and information flow. Openness can be achieved by involving the public at all stages of planning, research and development, implementation and management. Public meetings and hearings that explain the technology and risk assessment, in laymen's terms, can alter the public's perceptions. Information flow from scientists and managers to the public through publications, reports and the media can also help. Education can dissolve the barrier between ignorance and understanding and make the paradigm shift to a new technology easier.

ECONOMICS

On a strictly economic basis, landfilling and incineration tipping fees (cost per ton to receive waste at a treatment facility) of untreated MSW have steadily increased (Figure 2).

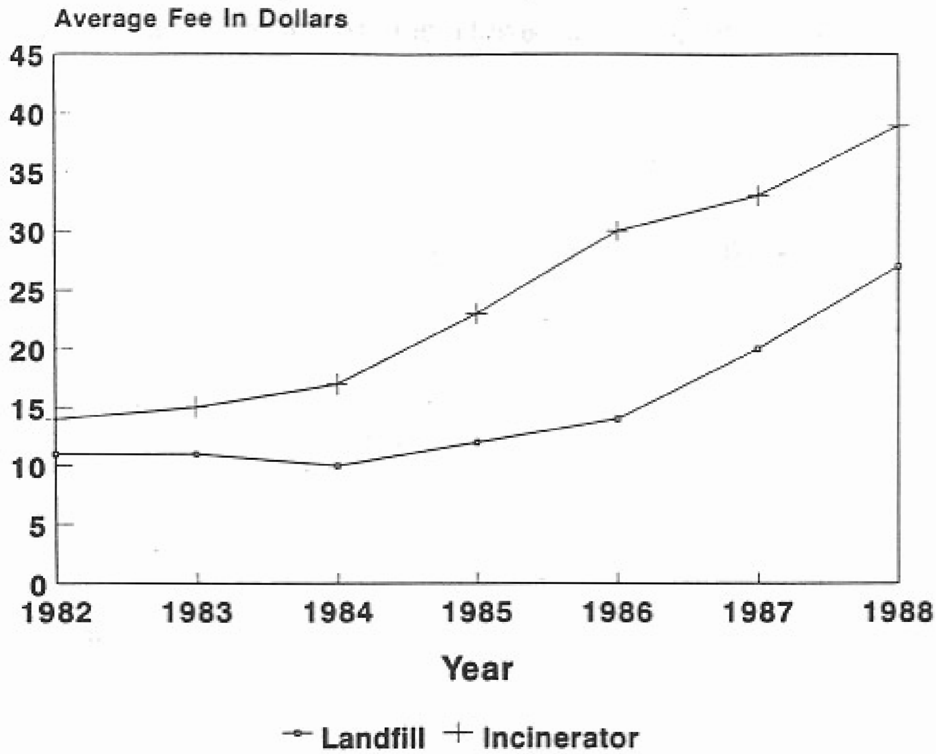

Figure 2. Change in Waste Disposal Fees.
Adapted from: Blumberg and Gottlieb 1989 War on Waste.

This high economic cost is due to tightening emission regulations, (requiring expensive pollution control systems); and increasing land values and lack of space for landfilled materials (higher fees stimulate the use of alternative waste management methods). Shortsleeve and Roche (1990) compared both IWM and mass burn facilities on an economic basis (Table 4). They modelled two facilities, both handling 300,000 tons of waste per year and paying the same price for utilities and residue disposal. Although annual operating costs are higher for IWM, initial capital costs are lower, and annual revenues are higher than those for mass burn respectively. In addition, IWM reduces the volume of waste to be landfilled, thus reducing annual landfill costs. The net result is a lower tipping fee and lower overall economic cost of waste disposal.

Table 4. Cost Comparisons between IWM and Mass Burn Systems.

	IWM	MASS BURN
Thruput in Tons	300,000 (Burn: 196,000) (Recycle: 59,000) (Compost: 45,000)	300,000
Capital Cost	$102.5 m.	$110.5 m.
Operating Cost	$9.5 m.	$8.2 m.
Annual Revenue	$9.9 m.	$9.2 m.
Annual Landfill Cost	$2.7 m.	$4.3 m.
Net Tipping Fee	$47.36/ton	$55.02/ton

Adapted from: Shortsleeve and Roche 1990 Analyzing the Integrated Approach.

Lower disposal fees, revenues from recovered materials and from energy sold and reduced disposal costs of less voluminous residues shows that a net economic advantage is gained through integrated waste management.

ENVIRONMENTAL AND SOCIAL COSTS

When analyzing the costs and benefits of IWM, environmental and social costs must be considered in addition to economic costs. The environmental costs (hazardous emissions) and social costs (siting and aesthetic concerns) associated with waste disposal can be high. Integrated waste management can reduce these costs.

Decreased volume of waste going to a landfill, can reduce the size as well as the environmental impact of the landfill. Recycling benefits include conservation and efficient use of both renewable and non-renewable natural resources. Incineration technological advances have drastically reduced airborne emissions and toxicity of residues. Additionally, a lower volume, less toxic ash is easier to dispose of and control leachates to groundwaters. The result is lower environmental costs.

Less environmental impact also means less social impact. Lower emissions lead to fewer health risks, smaller landfills lead to fewer aesthetic concerns when siting, and public participation in waste disposal methodologies leads to greater social satisfaction with government and industry. All of these total to a net decrease in social costs.

SUSTAINABLE DEVELOPMENT

Sustainable development can be defined as "any economic activity that raises social welfare with the maximum amount of resource conservation and the minimum amount of environmental degradation allowable within given economic, social, and technical, constraints" (Barbier 1987). It is a socially, economically and environmentally viable relationship between people and the environment they inhabit. Intuitively, IWM appears to be in agreement with sustainable development. However, quantifying and qualifying the economic, social and environmental costs and benefits together is virtually impossible. Economic and social costs are anthropocentric while environmental costs are non-anthropocentric. Because of this fundamental difference, comparisons between socio-economic and environmental systems are difficult. Economic analysis is possible by quantification of costs and benefits gained. Some social costs (aesthetic and health impacts) can be converted to monetary value and quantified for comparison with economic indicators. However, qualitative factors such as public confidence and satisfaction are virtually impossible to quantify, making comparisons difficult if not impossible. Environmental costs are the most difficult to either quantify or qualify, especially if taken in a non-anthropocentric context. What is needed is an analytical framework for comparing social, economic and environmental costs and benefits.

Barbier (1987) suggests that development as a process is "an interaction among three systems: the biological (and other resource) system (BS), the economic system (ES), and the social system (SS)." These three systems can be shown to interact in a basic diagram as shown in Figure 3.

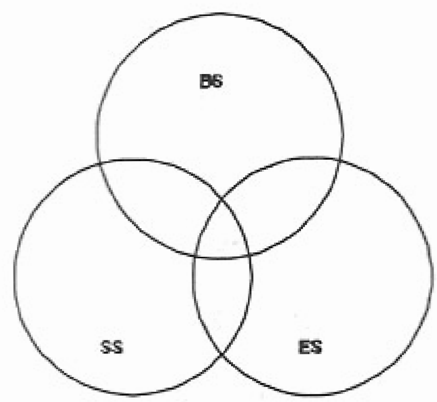

Figure 3. Biological (BS), Ecological (ES), and Social Systems (SS) Interactions.
Adapted from: Barbier 1987 The Concept of Sustainable Economic Development.

As each system has a set of goals,

- minimize environmental impact - BS
- minimize social impact - SS
- minimize disposal cost - ES,

the objective of sustainable development with respect to IWM is "to maximize the goals across all of these systems through an adaptive process of trade-offs, as illustrated by the shaded area in Figure 3" (Barbier 1987). Although the exact location of IWM cannot be pinpointed, IWM appears to meet the requirements of sustainable development as defined by Barbier.

In *Caring For The Earth - A Strategy for Sustainable Living* (IUCN 1991) sustainable development is defined as "improving the quality of human life while living within the carrying capacity of supporting ecosystems". This can be accomplished by living by nine principles proposed by the Strategy. Of the nine principles, five can be directly applied to IWM:

•Respect and care for the community of life.

This "means that development should not be at the expense of other groups or later generations" (IUCN 1991). IWM can reduce volume of waste and provide more stable long term disposal. This can conserve space for future landfills and minimize both short and long term adverse impacts to local environmental conditions.

•Conserve the Earth's vitality and diversity.

This principle is directed at actions that "protect the structure, functions and diversity of the world's natural systems" (IUCN 1991). IWM methods can minimize detrimental impacts to air and water quality as well as reduce the use of renewable resources.

•Minimize the depletion of non-renewable resources.

IWM focuses on multiple use of materials in the same or modified forms. Non-renewable resources such as minerals and oil can be conserved through IWM methods.

•Change personal attitudes and practices.

IWM depends on the use of open communication and education for the success of waste treatment policies. This can stimulate a change from an 'out of sight out of mind' attitude to accepting personal responsibility for waste generation and ultimate disposal.

•Enable communities to care for their own environments.

The concept of IWM is adaptable to any of the multitude of different community sizes. Through IWM, communities can assume a more active, responsible role in disposing of the waste they generate. In addition to being part of the waste management process, communities can insure that their local environments are not contaminated by garbage.

Although all of the concepts of sustainable development as defined in the Strategy do not apply to IWM, some of the criteria for sustainable development are met. Sustainable development and IWM can provide a framework for decision making about waste treatment policies.

CONCLUSION

I have shown that the technology is available for IWM to be successful in waste management methodology. The concept of IWM is dynamic and adaptable. It can be modified and applied to any waste stream no matter how large or small, and adapted to any combination of wastes in any municipality. It is cost effective, environment friendly, and has the potential of being socially acceptable and beneficial. The biggest barrier to its success is public acceptance. Public apprehension about waste treatment methods is stimulated by perceived risks based on the past reputation of treatments. Education and participation are the keys to the success of the IWM strategy. Educating the public about the real risks of waste treatment can alleviate their fears and heighten their responsibility for proper waste management. Allowing full participation of the public during research, planning, implementation and management of IWM policies can contribute greatly to the success of IWM. Finally, the concept of IWM is compatible with sustainable development; it has the potential to be the future of waste disposal ideology.

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