THE APPLICATION OF EXPERIENCE IN EUROPEAN INTEGRATED WASTE MANAGEMENT TO LATIN AMERICAN CONDITIONS

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Summary

Integrated Waste Management (IWM) is an approach to design, continuously improve and monitor the solid waste management system for a community, or region. IWM can be used by waste management designers and operators to ensure that waste management systems are environmentally effective, economically affordable and socially acceptable for a particular region and circumstances. IWM can point both government and industry towards sustainable solutions to managing solid waste. ERRA - European Recovery & Recycling Association - surveyed and characterized several IWM programs in Europe. Key drivers for the implementation of IWM have been identified and will be reported . Detailed results will be presented and references provided. The implementation of IWM in practice can be supported by the use of Life Cycle Assessments (LCA) and particularly its abbreviated form, Life Cycle Inventory (LCI). LCI assesses the use of resources (including energy), and the release of emissions to air, water and land, and the generation of useful products from waste. LCI is a decision support tool and can help planners and waste managers design more sustainable integrated waste management systems for the future. LCI computer models for solid waste exist and have been applied in some regions in Europe and North America.

1. Elements of an Integrated Waste Management Policy

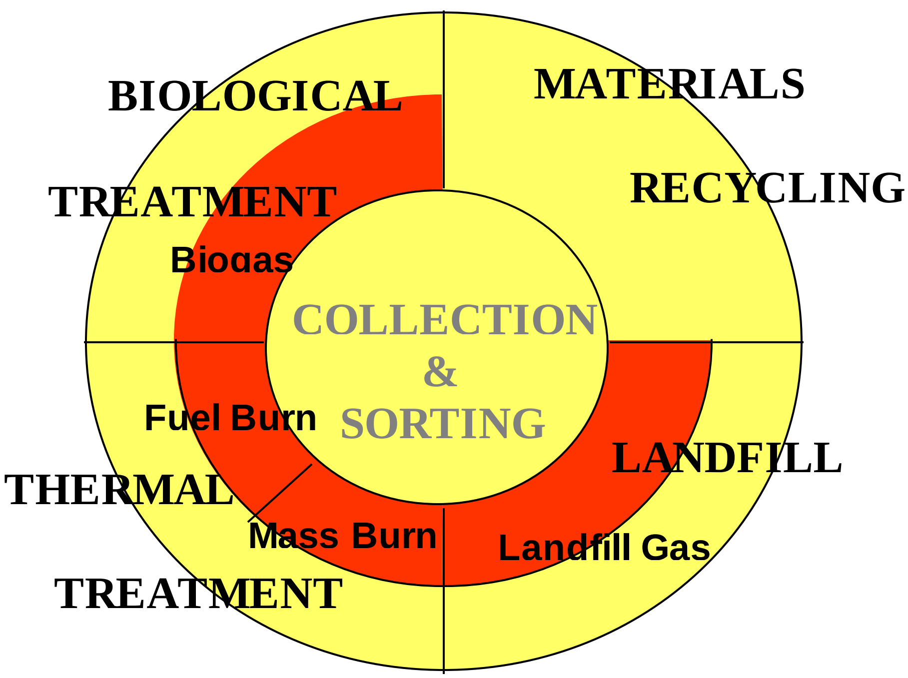
Integrated Waste Management (IWM) is a concept which is often quoted, but seldom defined. The objective of waste management is to effectively manage waste through optimizing resource conservation, optimizing the use of treatment technology and limiting the final disposal. The principle of IWM provides a flexible framework to achieve this objective. It avoids the danger of " general" solutions which ignore the unique characteristics of each region's municipal solid waste situation and programs.

IWM integrates solid waste streams, collection and treatment methods, environmental benefit, economic optimization and social acceptability into a practical and sustainable system. IWM combines a range of treatment options including recycling, composting, biogasification, incineration with energy recovery and landfilling.

The key point is not how many waste management options are used, nor whether they all apply at the same time, but that they are part of a single approach. For example, an ‘integrated system’ in one municipality which incorporates recycling, incineration with energy recovery and landfill may be quite unlike another municipality’s ‘integrated system’, which includes recycling, composting and landfill. This is not important as long as one retains the single overriding objective of the IWM principle: to find the most appropriate economic and environmental means available to divert an optimum amount of waste from final disposal.

Figure 1 shows different waste treatment options including landfilling which should form the basis for an Integrated Waste Management Policy.

Figure 1
Elements of Integrated Waste Management



1.1. The Principles of Integrated Waste Management

To optimally manage solid waste, certain principles should be adhered:

1. Integrated Waste Management (IWM) considers all options of collection, materials recycling, composting, biogasification, incineration with energy recovery and landfilling in an integrated system. IWM addresses the entire solid waste stream and not just sub-streams such as packagings. Separate systems for recycling only are in most cases not environmentally effective or economically efficient.

2. Shared Responsibility - Each participant in the production and solid waste management system (raw material suppliers, manufacturers, distributors, retailers, consumers, waste industry, government) has a distinct role to play in supporting successful Integrated Waste Management systems. In addition, each party is responsible for the correct disposal of solid wastes they create when they own a material or product.
3. Balance of criteria - An optimum system will have to achieve a balance between the following criteria:

   - Environmental Effectiveness
     Minimize the environmental effects of the overall system so that it becomes environmentally sustainable.
   - Economical Efficiency
     Minimize the costs of the system so that it becomes affordable and therefore economically sustainable.
   - Social Acceptability
     The above criteria must be met within a framework that is acceptable to the users of the system in their country or region.

4. Flexible applications for different communities/regions - Each community uses the criteria that best meets its particular local/regional needs and circumstances to determine the optimum collection, recovery and waste processing options.
5 Transparent costs for waste management - Services used and the costs of these services should be obvious and transparent to those who put solid waste materials into the solid waste management system.
6 Market oriented recovery and recycling - Materials (e.g. glass, paper, metals, and also compost) should be recovered from the solid waste system only when there is a market demand and therefore a market price for them and their recovery meets the environmental, economic and social criteria within a framework acceptable to the users and the people living in this country or region.
7. Appropriate Economy of Scale - Systems should be planned on an appropriate scale, combining jurisdictions if necessary, to support a range of treatment options that benefit from economies of scale.
8. Promote continuous improvement - Dealing effectively with waste is a relatively new challenge. The waste management industry is constantly evolving and while operational data are becoming more available, they are still limited. Hence, assessment is difficult and flexibility is essential to encourage continuous improvement of processes, to pursue best available technology and to customize solutions. All of these are necessary to accommodate shifts in the quantity and quality of the waste stream.

2. The Current Situation in Europe

Waste management policies across Europe are being developed in a complicated and costly manner. Based on EU (European Union) legislation, waste policies have been focusing on specific sectors, products and packaging. This fragmented approach is neither economically efficient nor environmentally effective.

2.1. The Hierarchy of Waste Management

In Europe, decisions on waste management strategies have often been based on “ The Waste Management Hierarchy” . This is a ranking of different waste management options, that is intended to give a broad indication of their relative environmental benefits. This hierarchy of preferred options often varies (and in certain waste management circles the exact order is hotly debated), but normally resembles the order: waste reduction, re-use, recycling, composting, biogasification, incineration with energy recovery, incineration without energy recovery and landfill. Taken as a rigid hierarchy rather than as only an indicator, it does not allow for the flexibility required when selecting the most environmentally effective and economically efficient method of waste management for any specific scenario.

ERRA - European Recovery & Recycling Association - does not support the rigid framework of the Waste Management Hierarchy as the sole source of guidance because of the following limitations:

The hierarchy approach is unable to compare the environmental advantages and disadvantages of different solid waste treatment options.
The hierarchy does not address costs and does not lead to economically efficient waste management systems.
There is little scientific or technical basis for listing the waste treatment options in this order.
Therefore, there is no recovery option which is always and in all regions preferred over any other recovery option (e.g. recycling, always preferred vs. incineration with energy recovery). All recovery options (recycling, composting, biogasification, incineration, landfill) have to be considered during the development of a fully Integrated Waste Management strategy.

Currently, many Europeans involved in the manufacture, distribution, consumption and post-use handling of residual products and materials find themselves confronted with more and more sectoral and fragmented waste systems, restrictive legislation and imposed responsibilities. These are leading to increased bureaucracy and costly processes without there being any clear indication of environmental benefit. The costs of goods and services subjected to such systems are rising and barriers to trade within the EU will proliferate.

Germany, which has championed the sectoral and fragmented approach since 1991, has seen the cost of municipal waste management surge by 84.5% between 1991 and 1995. This huge increase comes on top of the 2.5 to 3 billion $US paid each year by the German public for the Dual System Deutschland (or so-called " Green Dot System" for Packaging Recovery).

European householders in countries with operational recovery schemes are at present paying at least twice. For instance, they are paying for general waste services in their local taxes and they are paying with higher consumer prices for separate packaging collection and sorting services, e.g. in Germany, Austria, Belgium, France, Spain, and Portugal. If all waste management were to be handled in an integrated and cost transparent manner this could be done at little or no extra costs compared to solid waste disposal.

It is time to move the focus of the debate on solid waste towards a more holistic approach, namely, managing the total waste stream in a integrated manner.

3. Case Studies on Integrated Waste Management

The aim of the project sponsored by the European Recovery and Recycling Association (ERRA) was to demonstrate that Integrated Waste Management is a realistic and practical approach. A specific aim of the case studies was to characterize " leading edge" waste management systems in Europe and identify (if possible) common factors that have influenced in the past or are currently influencing IWM system development. Eleven IWM systems were selected, based upon information suggesting that operational or planned waste management strategies are considered advanced in the host countries.

3.1. The Role of Legislation

Enabling legislation allows for flexibility (and therefore integration) by making clear definitions of responsibility between players and by setting goals e.g. “ minimum standards” . In contrast, prescriptive legislation restricts flexibility (and therefore integration) by defining the means by which specific goals must be reached. For example the European Packaging and Packaging Waste Directive, which prescribes that a fixed percentage of specific packaging materials must be recycled, was seen to influence the studied IWM systems in different ways. In some instances it has changed how systems operate, in others it has not. This has depended essentially on the stage of development of the waste management system.

If a region has a well developed IWM infrastructure such as Copenhagen, no changes to its Integrated Waste Management system are required to fulfil the Packaging Directive targets because these are already being exceeded. In a city or region that has a developing IWM infrastructure there is the possibility that, due to the requirements of the European Packaging Directive, the waste management system focuses increasingly on the recovery of packaging and therefore less on a balanced integrated approach.

3.2. System Drivers Identified to Promote IWM

The following “ drivers for development” of IWM systems were identified during the development of the case studies. The concept of “ drivers” was defined as an event that results in a change in the *status quo* of an existing waste management system.

These identified “ drivers for development” of IWM are described as follows:
Good system management. This is as necessary in waste management as in any other business, decision making in both the long and short term must be based on accurate data.
Vision. It is essential that an individual or a team has a well defined and clear long term strategy on how to develop the IWM system.
Stability facilitates the development of a long term strategy, and is required both within the waste management department and within the political framework of the local authority.
Critical Mass (or: Economy of Scale) is essential for the development of major infrastructure and to ensure that necessary quantities of e.g. recycled materials, compost, biogas are available for systems to be established.
Landfill. The availability and cost of landfill space plays a major role in the development of waste management systems. Low cost (therefore often abundant) landfill can restrict the development of an integrated approach to waste management, while higher cost (often due to scarcity of) landfill can make other waste management options more economically viable.
Availability of funding, through grants, subsidies, partnerships or co-operative agreements are essential for development of major new infrastructure and upgrading of existing infrastructure.
Legislation, the effects of which can be both positive and negative. Enabling legislation improves flexibility and promotes an integrated approach to waste management, whereas prescriptive legislation has a restrictive effect (see 3.1. “ The Role of Legislation”).
Public opinion. Public support is essential for collection systems to function and for infrastructure development to take place. Communication through education campaigns, public consultation meetings and stakeholder dialogues increases awareness and understanding of waste management issues.
Control of all solid waste. Although this is important for reaching the “ Critical Mass” (or Economies of Scale), it is also essential that an established waste management system does not lose control of

waste streams. This can change an economically viable waste management system into an uneconomical system by forcing facilities to operate at below their initial design capacity. This increases the cost per tonne of the whole system.

3.3. Key Learning and Conclusions

- The variation between each of the case studies was seen to be extensive but common " Drivers" to promote the development of the IWM system were identified.

- Contrary to the common belief that considers environmental issues ahead of social and economic issues, there was common agreement amongst waste managers that in reality their priority order for sustainable waste management has generally been:

  - economic viability
  - social pressure
  - environmental benefits

- Environmental benefits cannot be engineered into the development of a waste management system unless that system is economically viable and socially acceptable, hence all three areas must be addressed simultaneously.
- An integrated approach to waste management is being adopted at a local level throughout Europe.

- Enabling legislation can have a positive impact on the development of effective waste management systems whereas prescriptive legislation can have a negative influence on both existing and developing waste management systems.

- The waste hierarchy was only considered to be useful as a list of possible treatment options.

- Data based decisions and flexibility are necessary at the local or regional level of waste management operations.

- There is also evidence for system evolution, from waste management practices, to Integrated Waste Management, and then to resources management.

4. Paying for Integrated Waste Management

4.1. Who should pay ?

The waste owner at the point of disposal should pay for waste management services. An integrated waste management system minimizes risks to public health and results in a clean healthy environment for all citizens. Local governments benefit by reduced health care costs and reduced urban management costs (as dumped solid waste does not block clean water supplies or sewerage services). Therefore Local Authorities should pass on their savings to those who pay.

4.2. How much to pay ?

The system must be affordable for all sections of the community but the full cost of the waste management system must be recovered to ensure that the system is sustainable. This is one of the great challenges of waste management.

4.3. How do you pay ?

Taxes and charges are the usual methods of payment for existing waste management systems, often this is not transparent (the true cost is not clear) and provides no incentive for the householder to spend any time or energy on reducing the amount of waste they generate. “ Pay as much as you throw” is a preferred alternative.

4.4. Shared Responsibility

The polluter pays principle states that the cost of environmental impacts should be paid by those who cause the pollution. This principle is also known as “ Shared Responsibility” . Shared Responsibility means, the wastes generated at each stage of a products lifecycle (raw material extraction, processing, manufacture, distribution and consumption) are the responsibility of the owner of the product at that stage. Shared Responsibility results in a system whereby the responsibilities of each individual in the supply chain are clearly defined and costs are allocated on the basis of the amount and types of waste generated. There is a financial incentive to reduce the amount of waste generated at each stage of the lifecycle.

4.5. The “Variable Rate” System

This principle of Shared Responsibility is now increasingly applied to payment for Municipal Solid Waste management services. The term “ Variable Rate” describes a system that charges householders according to the amount of waste they produce. Electricity, gas and water are metered and charged based on consumption, following this approach, waste management charges can be based on solid waste generation. The more waste you generate the more you pay, but importantly, reducing the amount of waste you generate means you pay less for your waste management service. This variable rate charge provides a clear financial incentive to the householder to modify his or her behavior to produce less waste.

This change in behavior can take two forms:
Increased participation of the citizens in recycling/composting programs, resulting in further potential benefit for the waste management authority.

Choosing and purchasing products and services that generate a minimum amount of waste. This provides a clear market driven message to the producers/manufacturers that designing lower final waste products is a positive marketplace attribute.

Table 1 lists some of the many case studies available that demonstrate the success: a reduction in household waste generation via the Variable Rate Systems.

Table 1:
Successful Variable Rate Systems

Variable Rate System	Reference	Results
Belgium, Hainaut Province	ERRA - European Recovery and Recycling Association, Brussels, Belgium, 1998	65% reduction in household waste sent to landfill in the first year
Belgium, Wallonia	ERRA - European Recovery and Recycling Association, Brussels, Belgium, 1998	Doubled participation rates for curbside collection schemes, resulting in a 40% reduction in waste going to landfill
Japan, Yono City	Warmer Bulletin, No. 64, 1999	13% reduction in burnable solid waste, 27% reduction in non-burnable solid waste
Netherlands, Oostzaan,	ERRA - European Recovery and Recycling Association, Brussels, Belgium, 1998	38% reduction in waste generated, 60% reduction in residual waste generated
Switzerland, Zürich	European Recovery and Recycling Association, Avenue E. Mounier 83, Box 5, B-1200, Brussels, Belgium. 1998. Also available at www.erra.be	Overall waste arisings fell and amount of material going to recycling increased significantly
USA, Mendham, New Jersey	World Wastes, Feb. 1993, pp.36-40.	55% reduction in waste going to landfill, 83% increase in recycling, 50% decrease in annual costs per household
USA, Nationwide survey	Nationwide Diversion Rate Study, Reason Foundation and SERA Inc. 1996	Survey confirmed the positive impact on recycling effectiveness and overall diversion rates
USA, Seattle, Washington	Skumatz., 1991 Garbage by the Pound: The potential of weight based rates. Resource Recycling, July 1991.	15% reduction in waste generated per householder

5. Life Cycle Inventory of Solid Waste

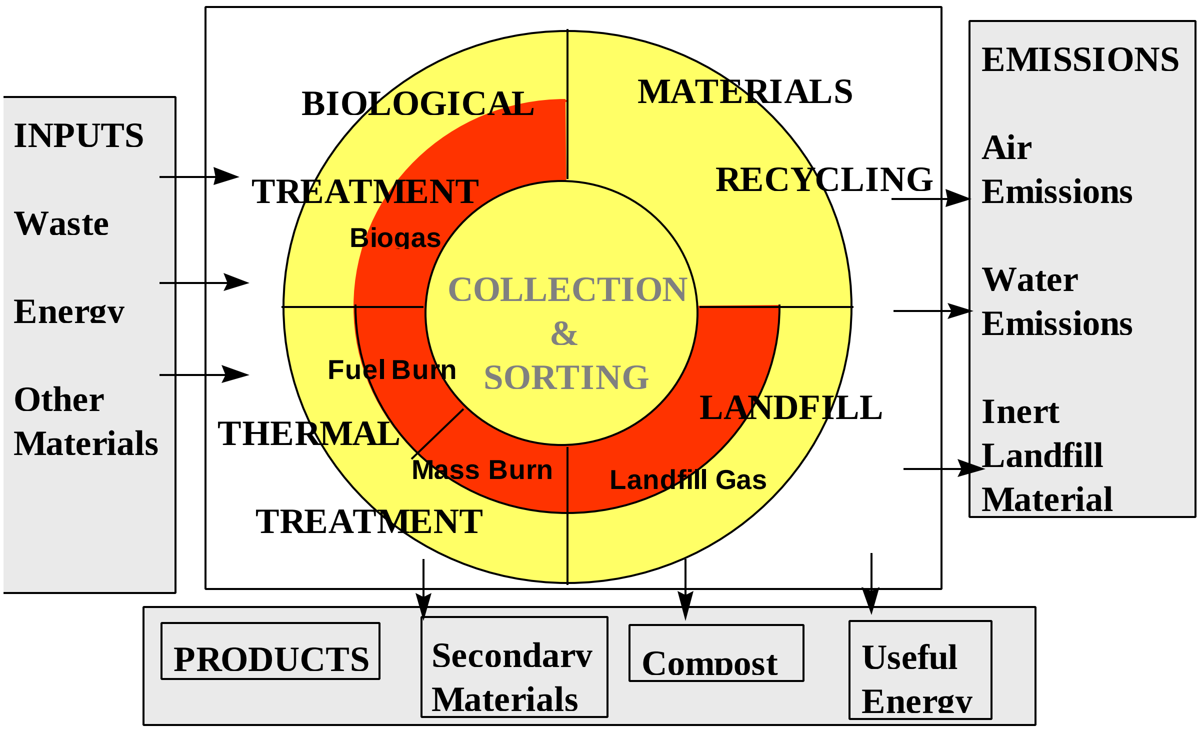
So far, Life Cycle Inventories (LCI) - not the full LCA's including Impact Assessments have been done for solid waste. The LCI of Municipal Solid Waste starts the moment a material becomes waste (i.e. loses value) and ends when it ceases to be waste by becoming a useful product, inert landfill material or an emission to either air or water.

The inputs for an Integrated Waste Management system are solid waste, energy and other raw materials. The outputs from the system are both useful products in the form of reclaimed materials, energy and compost, and emissions to air and water and inert landfill material.

Once the waste management system has been described, the inputs and outputs of each chosen treatment process must be calculated, using fixed data for each process. The lack of quality data is a recognized problem in this part of an LCA methodology.

The results of LCI models for solid waste are expressed as: net energy consumption, air emissions, water emissions, landfill volume (inert), recovered materials, compost, material recovery rate and landfill diversion rate.
The usefulness of LCI in waste management is in assessing environmental efficiency. Given that all the individual operations, such as composting, incineration, landfilling etc. are safe, LCI will help determine the optimal integrated combination of these options that minimizes energy and raw material consumption, and the generation of air and water emissions and final inert solid wastes.

Figure 2
Integrated Solid Waste Management: A Life Cycle Inventory



It also needs to be stressed that an LCI will not actually make any decisions about the “best” waste management strategy. A Life Cycle Inventory for solid waste management will provide a list of energy consumption, and emissions to air, water and land, over the whole life cycle, and will also predict the amounts of useful products that arise from waste, such as compost, secondary materials and useful energy (Figure 2). The best system for any region will depend on local needs and priorities, such as the need to reduce landfill requirements, or the desire to reduce water emissions or air emissions. Thus, LCI is a decision-supporting tool, not a decision-making tool. The selection of the best IWM system for any region will still require a decision to be made, but LCI can provide additional, overall environmental information for use in the decision-making process.

5.1. Current State of the Art: LCI Computer Models for Integrated Waste Management Systems

The first complete LCI computer model for waste management was released in 1995 as part of the book Integrated Waste Management: A Lifecycle Inventory (White *et al.*). The model predicted overall environmental inputs and outputs of Municipal Solid Waste systems and included a parallel economic model. The model was designed as a decision-support tool for waste managers in both industry and local government, who needed to decide between various options for waste management. The model was (and still is) used in Europe, South America and Asia to help design regional and local waste management systems. An improved version of this model, more flexible and user friendly, containing updated data is due for release early in the year 2000.

The US Environmental Protection Agency (EPA) is currently working to apply recent Life Cycle Assessment methods to develop tools for evaluating Integrated Waste Management. The research began in 1994 and is expected to be completed in 1999. The outputs from this research will include:

1) a database of Life Cycle Inventory data on the various solid waste components (i.e., glass, metals, plastic, and paper) and the different waste management activities (i.e., transportation, recycling/composting, landfilling, and combustion)
2) a decision-support tool for applying Life Cycle Inventory tools on a site-specific basis to evaluate different Integrated Waste Management strategies
3) case studies of several state and local governments applying the decision-support tool

The UK Environment Agency's Life Cycle Research program also began in 1994. The aim of the program is " to provide an objective basis for the comparison of waste management strategies and of options for individual waste types" . To this end the program is investigating the environmental inputs and outputs (of both energy and raw materials) and the related impacts of different waste management options from cradle to grave.

Two Canadian industry groups, Corporations Supporting Recycling (CSR) and the Environment and Plastics Industry Association (EPIC) have co-sponsored the development of a site specific tool that municipalities can use to evaluate the environmental and economic effects of proposed changes to their Integrated Solid Waste Management system, strategies and practices. This holistic system approach takes into account the upstream and downstream effects of waste management decisions. It is based on:

1) best data currently available
2) the consideration of selected environmental inputs and outputs
3) a municipal focus

The same LCI tools have also been applied to the realm of European-wide policy making. Two separate studies for the European Commission have used an LCI approach to compare the different waste management options.

The benefit of using a tool like LCI is that it provides flexibility by allowing assessment of the optimal waste management strategy for a given region, on a case-by-case basis, taking into account these factors. Hence LCI is best used as a case-by-case tool, rather than to try to identify a single solution for a whole country or continent. The role of policy should be to set the desired outcomes from waste management, such as energy conservation, or reduction of global warming potential. LCI can then provide an overall accounting tool to help reach these outcomes.

5.2. What Do The Users Say?

The benefits of using LCI in a case-by-case way can be seen from looking at the examples where it has already been used. To date LCI models have been used as:

- Benchmarking tools:- to assess the current environmental profile of a waste management system.
- Comparative planning tools:- to allow a series of "What if...?" scenarios to be investigated and compared.

- Communication tools:- to provide information on alternatives that can be shared with all interested stakeholders, including citizens.
- Sources of data:- to provide comprehensive and coherent data on all aspects of waste management.

There are many cases where LCI has been used to " inform" waste management decisions. The ultimate test of the value of LCI as a decision support tool, however, is to look whether it has influenced decisions. The answer is yes. In Barcelona, for example, the newly proposed waste strategy for the region was arrived at using an LCI study using the model published by White *et al*.. In Pamplona, the option of composting is now under consideration following an LCI study. London, Ontario have taken the step of formally incorporated an " Environmental Life Cycle Inventory and Economic Cost Analysis Model" in their Continuous Improvement System for waste management.

6. Implementation of IWM in developing economies

The process of converting current waste management systems to IWM within developing economies should contain the following steps:

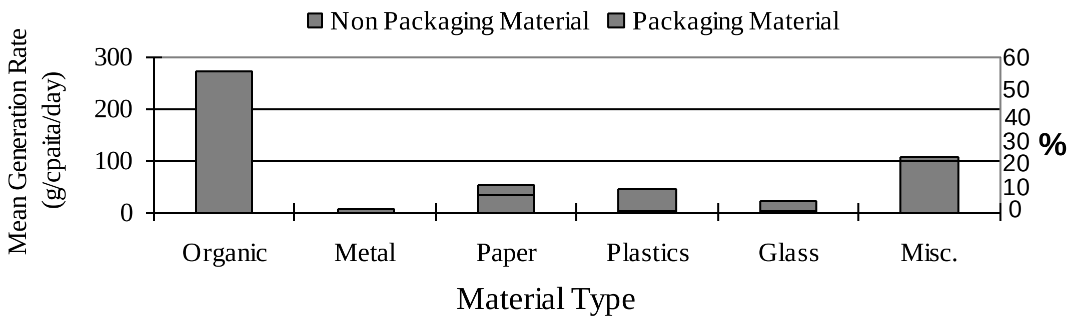
1. Data collection on waste composition. This will be relevant for any planning of collection, transport and treatment of MSW. Good data will be the foundation of an effective IWM program.
2. Progress from uncontrolled dumping to the use of simple sanitary landfill.
3. Separation of organic waste from MSW which can then be composted.
4. Formal involvement of scavengers in the collection of recyclable materials

Details on this implementation are given in the following chapters.

6.1. Data collection and waste composition

Although information on the composition of municipal solid waste (MSW) in developing economies is limited, a recent study by Bernache-Perez (1999) presents a relatively detailed analysis of MSW within the Guadalajara metropolitan zone of Mexico (GMZ). As in many developing economies, the major component of MSW was organic material including food waste and yard trimmings which accounted for almost 54% (by weight) of the total. Paper accounted for 10.4%, plastics 9.2%, glass 4.7%, metals 1.8% while miscellaneous material (cotton, fabrics, construction materials, leather, fine waste, etc.) constituted the final 20.9% of the total (Figure 3). Compositional differences between the waste collected in Guadalajara and that studied by Rathje (1985) in Tucson, Arizona are quite significant. Only 20% of the MSW collected in Tucson was food waste compared to 41% for the GMZ. Based on current knowledge and insights in developing economies this is due to the greater use of unprocessed foods in developing economies which results in the generation of large amounts of waste during preparation. This is supported by the fact that food waste in the GMZ study was made up largely of fruit peelings, vegetable waste, bones, etc. while that in the Tucson study was comprised mainly of meal remains. This may also help to explain the fact that while packaging waste is only 17.5% of MSW in the GMZ, it was found to be 41.2% of MSW in Tucson.

Figure 3:
MSW material type and amount in the Guadalajara Metropolitan Zone



6.2. Dumping and landfilling

Dumping of MSW into uncontrolled sites or indiscriminately is the most common form of waste disposal in the developing world and is the result of limited technical and financial resources. This method of final disposal is uncontrolled, is environmentally and socially unacceptable and does little to protect the environment or public health. Pollution of surface and groundwater by leachate, migration of combustible gases (methane), odours and breeding of disease carriers are all common results. Dumps provide very poor living conditions for scavengers and pose significant health risks today and in the future.

Landfilling stands alone as the only waste disposal method that can deal with all materials in the solid waste stream. However, landfilling is not a 'black hole' into which material is deposited and never leaves. Decomposition of the landfilled material occurs with the outputs from the process being the final stabilised solid waste, plus the gaseous and aqueous products of decomposition, which emerge as landfill gas and leachate. In most situations disposing of waste is the lowest cost option, even in the developed world where landfills are often highly engineered and include multiple liners on the bottom of the landfill. Liners are made of impermeable materials such as plastic film to stop the escape of leachate and reduce the risk of contaminating the groundwater. In most cases the leachate will be collected for treatment before being returned to surface water. In addition modern landfills incorporate in the designs gas collection systems. Landfill gas which consists mainly of methane can be burnt off or converted into biogas for energy recovery.

Moving away from a system based on dumping to one based on sanitary landfills represents the most financially realistic option for developing economies to improve waste management. Although the resources for highly engineered facilities are unlikely to be available, simple, low cost options are possible. Landfills should be sited away from water courses and highly populated areas and built on soils with a relatively low permeability such as clay. Filling should be on a cell basis where possible with the application of a cover of soil or compost (for details see section 4.3/4.4) at the end of each day. Organic waste and recyclable material should be separated before entering the landfill (for details see section 4.3) and the site should be fenced or positioned to limit access by trespassers. Implementation of these simple steps is likely to reduce or eliminate many of the problems associated with dumping.

6.2. Separation and treatment of organic waste

Separation of organic waste from the MSW stream represents an opportunity to reduce the quantity of waste entering landfills in developing countries by up to 50% (by weight). Correct treatment of this waste will also significantly reduce the pollution and health problems previously described by removing the major source of leachate, combustible gases, odours and food for disease carriers.

Separation of organic waste can occur at the households prior to collection, at the landfill prior to final disposal or a combination of both. Motivation of households to collect organic waste is required to ensure a high level of efficiency. Efficient separation of organic materials by householders will only be sustained if the source separation system is convenient, hygienic and beneficial. A comprehensive and simple educational campaign from the municipality or group of municipalities to the householders, before the householders are required to start collection of organic waste is advisable. Educational materials should be easy to understand and use pictures to explain what to separate. Education must also continue after the launch of the scheme, in an advisory and supportive manner, through the use of waste advisors, school programs and possibly consumer information telephone lines at least in the initial phase.
Separation at the landfill will require the organisation of labour/scavengers and must occur before final disposal to avoid separation by scavengers occurring in the landfill itself (for details see section 4.4).

Once separated the waste can be composted (in the presence of plentiful oxygen) or used to produce biogas (a process in the absence of oxygen). Composting systems range in their complexity and have been well described in the literature. With composting, organic material decomposes in the presence of oxygen to produce mainly carbon dioxide, water and compost. Considerable energy is released in the process which destroys any pathogens that may be present and is eventually lost to the surroundings. Biogas is produced following the anaerobic fermentation or anaerobic digestion of the organic fraction. This produces carbon dioxide, methane, water vapour and an organic residue. The methane can be collected for energy recovery.

Markets and uses for the compost will depend on local conditions and needs. In Bombay, India, 300 tonnes of municipal solid waste is composted to yield 60 - 70 tonnes of compost per day. The compost process is using a simple ‘windrow’ method, the compost is sold to farmers generating a profit of approximately US$10 per tonne (Panjwani, 1998). In other countries, the soil displaced to create the landfill may have more value than the compost. In certain parts of Argentina (e.g. around Buenos Aires)where the soil is of very high quality, the selling of compost may not be economically viable. Instead, the compost may be used to cover the landfill and the displaced soil might be sold which generates more revenue than by selling the compost (Franke, personal communication).

6.3. Recycling and Scavenging

Scavenging occurs at a number of stages within the MSW management stream. ‘High quality’ recyclables such as entire glass containers, plastic bottles, metals, etc., are often collected door-to-door by individuals or by the waste collectors themselves (Bernache-Perez, 1999). This may or may not involve the exchange of money or other items such as garlic in India, which is a common practice in some regions of Bombay (Franke, personal communication). Recyclable material may also be sorted at the curbside by people searching through garbage containers and by people scavenging at the landfill/dump (Nagpal et. al, 1999). It is this latter form of scavenging that poses the greatest threat to health, represents the poorest living conditions and as such is most urgently in need of improvement. Nagpal et. al, (1999) has suggested that plastics recycling in India would be improved by the establishment of deposit centres for post-consumer plastic waste. This would help ensure that higher quantities of plastic waste are deposited by users and salvaged by waste-pickers. Once deposited, plastic waste can be taken to licensed recycling units which have the added benefits that product quality can be monitored and tax evasion avoided.

Scavengers need to be formally involved in the sorting, collecting and recycling of materials. This has been achieved at low cost in the suburbs of Mexico City by the construction of a simple material recovery facility where some of the collected waste (approximately 1500 tonnes per day) is placed on a series of conveyor belts to be sorted by scavengers. Materials recovered by the sorters are further cleaned and processed for sale. All of the various pieces of the equipment in the facility were specially designed so that they could be built and maintained in Mexico (Diaz, 1994). The construction of a materials recovery facility of this type offers a number of benefits including: a) improved working conditions for the scavengers who no longer have to sort materials on the landfill itself, b) an opportunity for scavengers to increase their income by pooling recyclable material to be sold in bulk, and c) an increase in recycling and landfill diversion rates, d) children have the opportunity to attend school rather than work as scavengers, and e) modest accommodation is provided for the scavengers and their families at an affordable rate which is paid for out of the money they earn for separating recyclable materials (Diaz, personal communication; Garmendia, personal communication). In Brazil, with the help of non profit organisations and industry, the training and organisation of scavengers has allowed them to offer a reliable public service as part of the waste management system (CEMPRE, 1999).

Formal organisation of scavengers would also allow them to earn extra income by assisting with the separation of organics, composting operations and covering of waste with soil/compost.

A good example here is the Madras based non-governmental organisation " CiviExnora" . Exnora have assigned streets to scavengers who take care of street sweeping, collecting of garbage, sorting of recyclables and disposing of the rest waste to the nearest municipal transfer sites. The scavengers also collect organics in some streets separately. They bring the organics to a kind of " backyard composting" site. Here the organics are composted via a very simple method in containers with holes to allow aeration and composting subsequently. This " backyard composting" is possible because the organics contain only a minimum or no meat or bones due to the special vegetarian diet in India. Otherwise meat or bones could cause problems because they do not compost well in a simple backyard composting process in which no optimum composting conditions (e.g. optimum temperature, moisture) and subsequently no sanitisation of compost can be guaranteed. The compost is used for gardening in the streets and yards in which the organic waste is collected separately. Exnora calls this project the " Zero Waste" project because the rest waste to be disposed is minimised since recyclables and organics are recovered (Franke, personal communication).

6.4. Incineration

Incineration of waste can be conducted with or without energy recovery. Although an essential element of many IWM systems in the developed world it is expensive to implement and is unlikely to be a realistic option for developing economies. However, the previously described strategies that can be implemented in such developing regions will serve to lay the foundations for energy recovery from waste in the future as these economies develop. This is particularly important in the case of separation of organic, highly putrescible waste from the MSW stream. Organic waste significantly increases the moisture content and decreases the calorific value of MSW. Its removal is the first step towards preparing waste for incineration.

7. Conclusions

Although limited by technical and financial resources, countries with developing economies have the potential to significantly improve waste management. Implementation of certain elements of IWM as practised in Europe and other developed regions of the world presents the opportunity to establish waste management systems that are both environmentally, socially and economically acceptable. Moving from open dumping to simple sanitary landfills in conjunction with separation and composting of organic waste is likely to result in significant benefits. Pollution of surface and groundwater by leachate, migration of combustible gases (methane), odours and breeding of disease carriers would be minimised. Living conditions of scavengers would be improved and health risks reduced. Their formal involvement in the sorting, collecting and recycling of materials would offer the potential to supplement their income and increase recycling rates. A careful analysis of market conditions for recyclates and compost must be conducted to prevent unbalances that could affect their price.

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